Proceedings of the Eighth Dredging Seminar

Prepared By

CENTER FOR DREDGING STUDIES

J. B. Herbich, Ph.D., P.E., Director

CDS Report No. 195

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December 1976

TEXAS A&M UNIVERSITY SEA GRANT COLLEGE

PROCEEDINGS

OF THE

EIGHTH DREDGING SEMINAR

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EIGHTH ANNUAL DREDGING SEMINAR
HOLIDAY INN - MEDICAL CENTER, HOUSTON, TEXAS
NOVEMBER 8, 1975

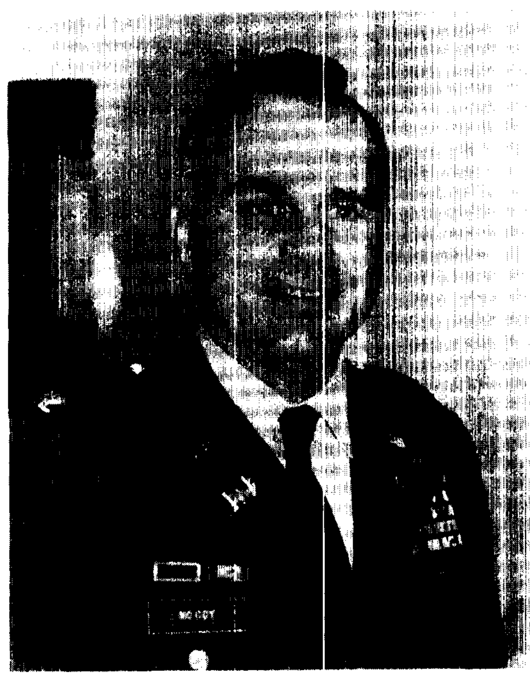
Morning Session		*Moderator: Dr. John B. Herbich*
8:30 - 9:00	*Registration*	Hotel Lobby
9:00 am	*Welcoming Address*	Dr. John B. Herbich, Center for Dredging Studies, Texas A&M University
9:10 am		"Physical Factors Affecting Dredged Material Islands in a Shallow Water Environment", James Stinson, II, Christopher C. Mathewson, Department of Geology, Texas A&M University
9:50 am		"A New Concept for Dredged Material Disposal", Michael R. Palermo, Raymond L. Montgomery, Design & Concept Development Branch, Environmental Effects Laboratory, USAE Waterways Experiment Station
10:30 am	*Break*	
10:50 am		"Dredging Operations in the Galveston District", Colonel Don S. McCoy, District Engineer, Department of the Army, Galveston District Corps of Engineers
11:35 am		"Dredge Material Containment in Nylon Bags in the Construction of Mini-Projects for Beach Stabilization", Jerry L. Machemehl, Ph.D., P.E., Assistant Professor Dept. of Civil Engineering, North Carolina State University, Raleigh, North Carolina
12:15 n	*Luncheon*	Mr. Vladi H. Vonas, Lockwood, Andrews and Newman, Inc., Houston, Texas, presiding. Speaker: Commander T.C. Volkle, U.S. Coast Guard, "Vessel Traffic System Houston-Galveston".
	Afternoon Session	*Moderator: Dr. Robert E. Schiller, Jr.*
1:30 pm		"National Dredging Study", William R. Murden, Office of the Chief of Engineers, Department of the Army, Washington, D.C.
2:20 pm		"An Investigation of the Environmental Impacts Associated with the Disposal of Dredged Material at the Offshore Disposal Site, Galveston, Texas", Mr. David B. Mathis and Stephen P. Cobb, Environmental Effects Laboratory, U.S. Army Engineers Experiment Station, Vicksburg, Mississippi (Abstract only)

3:05 pm	*Break*	
3:20 pm		"Use of Remote Sensing in Evaluating Turbidity Plumes", Dr. Wesley P. James, Coastal, Hydraulic & Ocean Engineering Group, Texas A&M University
3:55 pm		"Hydrologic and Sedimentologic Study of the Offshore Dredge Disposal Area, Savannah, Georgia", Dr. George F. Oertel, Skidaway Institute of Oceanography, Savannah, Georgia
4:25 pm		"Aquatic Disposal of Dredged Material; Release of Contaminants During and After Disposal", Dr. Robert M. Engler, Dredged Material Research, U.S. Army Engineers Experiment Station, Vicksburg, Mississippi
4:55 pm	*Discussion and Announcements*	
5:15 pm	*Adjournment*	

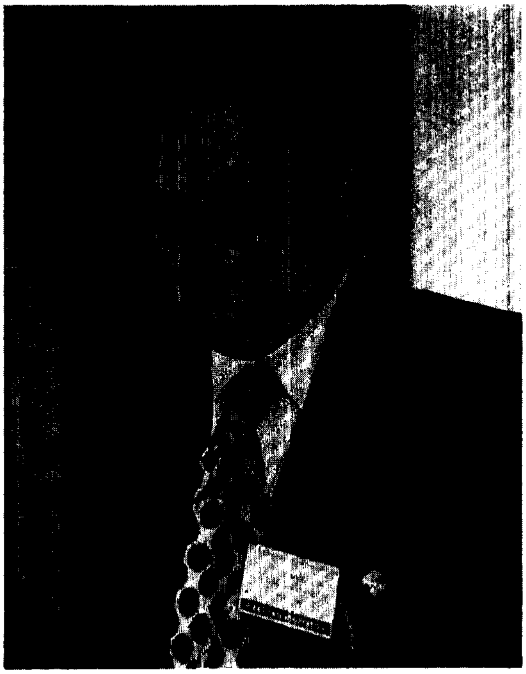
Dr. J.B. Herbich
Texas A&M University

James E. Stinson, II
Texas A&M University

Michael R. Palermo
USAE Waterways Experiment Station



Colonel Don S. McCoy
U.S. Army Corps of Engineers



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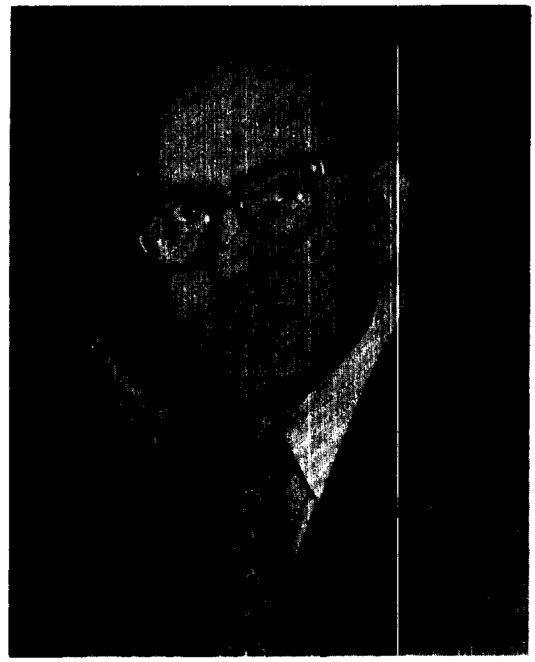
North Carolina State University



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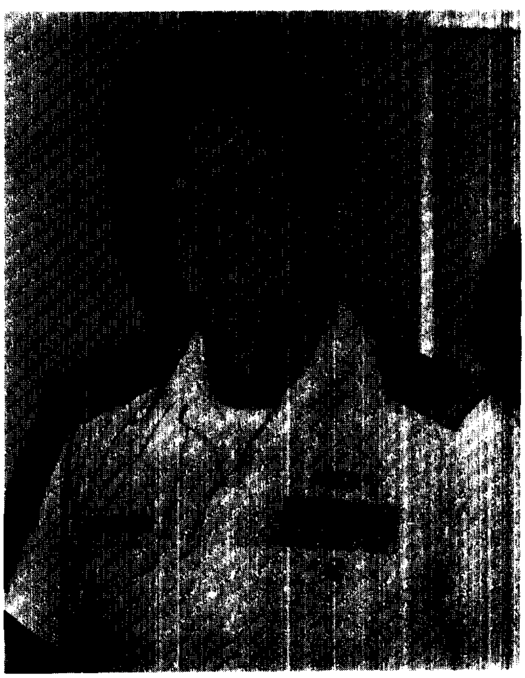
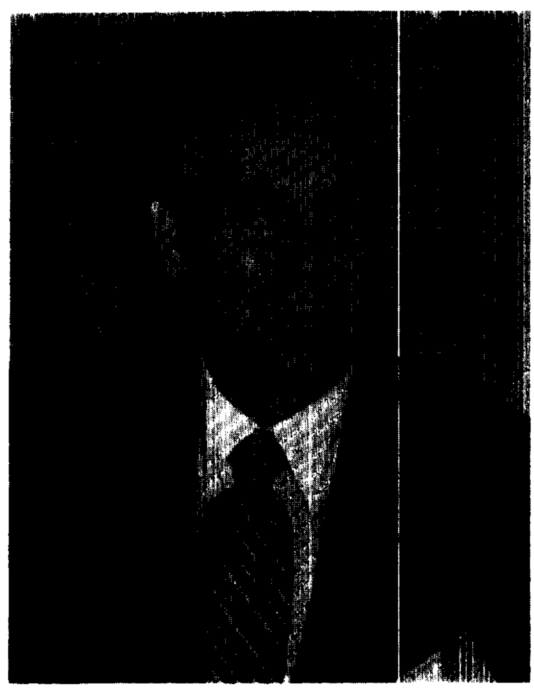


Commander T.C. Volkle
U.S. Coast Guard



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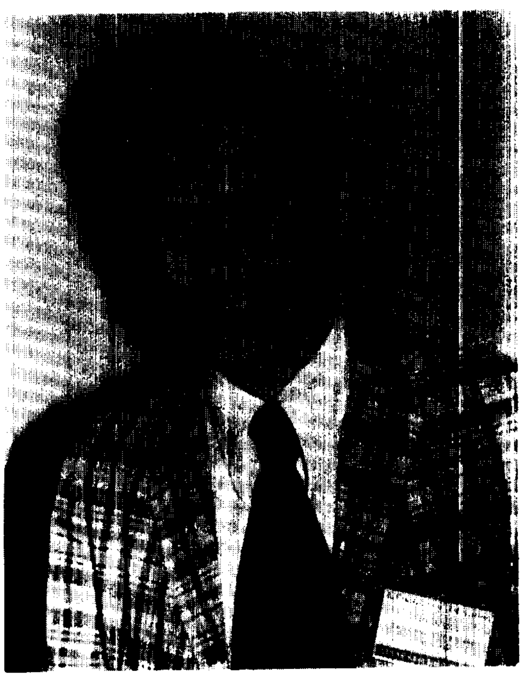
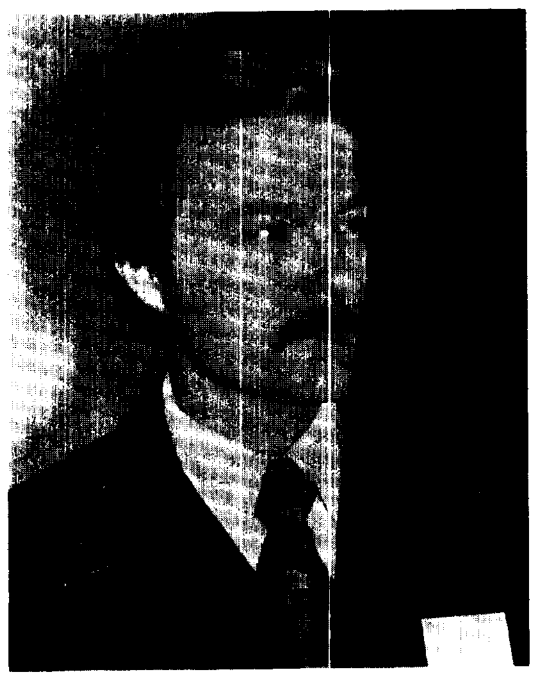


Dr. George F. Oertel
Skidaway Institute of Oceanography



Dr. Robert M. Engler
USAE Waterways Experiment Station

ACKNOWLEDGMENT

The Seminar was arranged by Dr. John B. Herbich as part of the continuing educational activity of the Center for Dredging Studies.

The Proceedings were assembled and edited by Dr. Herbich. Editorial assistance of Dr. Gisela Mahoney was greatly appreciated.

The Seminar was partially supported by the Oceanic and Atmospheric Administration's Sea Grant Program Institutional Grant 04-6-158-44012 to Texas A&M University.

Mrs. Vicki Jamison and Mrs. Debi Brendel typed the manuscript for publication.

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PHYSICAL FACTORS AFFECTING DREDGED MATERIAL ISLANDS IN A SHALLOW WATER ENVIRONMENT

by

James E. Stinson, II*
Dr. Christopher C. Mathewson

ABSTRACT

Regional geologic processes should be considered when choosing locations for dredged material disposal sites. Topography, bathymetry, geomorphology, meteorology and water circulation must be examined for a full understanding of the active processes and their effects. Winds and waves are the physical factors considered to be most dominant. Winds control sand transport across Padre Island, water levels and circulation in Laguna Madre and define the direction of current and sediment movement. Erosion and shoaling of dredged material by waves in the lagoon parallel the geomorphic trends of the area. When using open water disposal methods while dredging channels the dredged material should be placed on the downdrift side of the channel to avoid the return of sediment to the channel.

INTRODUCTION

Dredged material placement has recently come under heavy criticism by various environmental and wildlife interest groups. These groups are concerned with the effects of dredging and disposal on the present habitats adjacent to the dredging sites. Agencies in charge of site selection have taken into consideration the requests of the interest groups but in many cases they have failed to consider the physical factors that are continually affecting these sites. A carefully planned disposal

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area which protects and enhances the flora and fauna is unsuccessful if the dredged material does not stay in the disposal area but returns to the channel, necessitating extensive channel maintenance.

As part of a SEA GRANT project studying sand transport and the silting mechanisms on Padre Island and in the adjacent Laguna Madre, the problem of channel infilling was examined. Initially, it was believed that shortlived phenomena such as floods, tidal surges, severe storms, and hurricanes would have the greatest impact on the islands and channels in Laguna Madre and on Padre Island. Although these phenomena do have an effect, it was found that daily ongoing processes control the changes on Padre Island and in Laguna Madre.

The study area includes Padre Island and Murdock Basin in Laguna Madre near Yarborough Pass, bounded on the south by Middle Ground, the east by the Gulf of Mexico, the west by the mainland and the north by Baffin Bay (Figure 1).

Dominant forces in the study area are winds and waves. Wind roses compiled from data back to the late 1800's show a dominant wind direction from the southeast during the warmer months of the year and an increased frequency of north winds during the winter months (Figure 2). Wind velocities for the southeast prevailing winds are usually 12 to 20 mph (19 to 32 km/hr) as compared to the north winds which may exceed 50 mph (80 km/hr) during storms. Physical features reflecting the wind effects are the banner complexes on Padre Island, oriented to the direction of the prevailing southeast winds, and the dunes on the aeolian plain on the mainland which display a northwest-southeast lineation paralleling the direction of the prevailing winds. On the coast, the winds from the southeast generate waves causing a northward longshore current. This

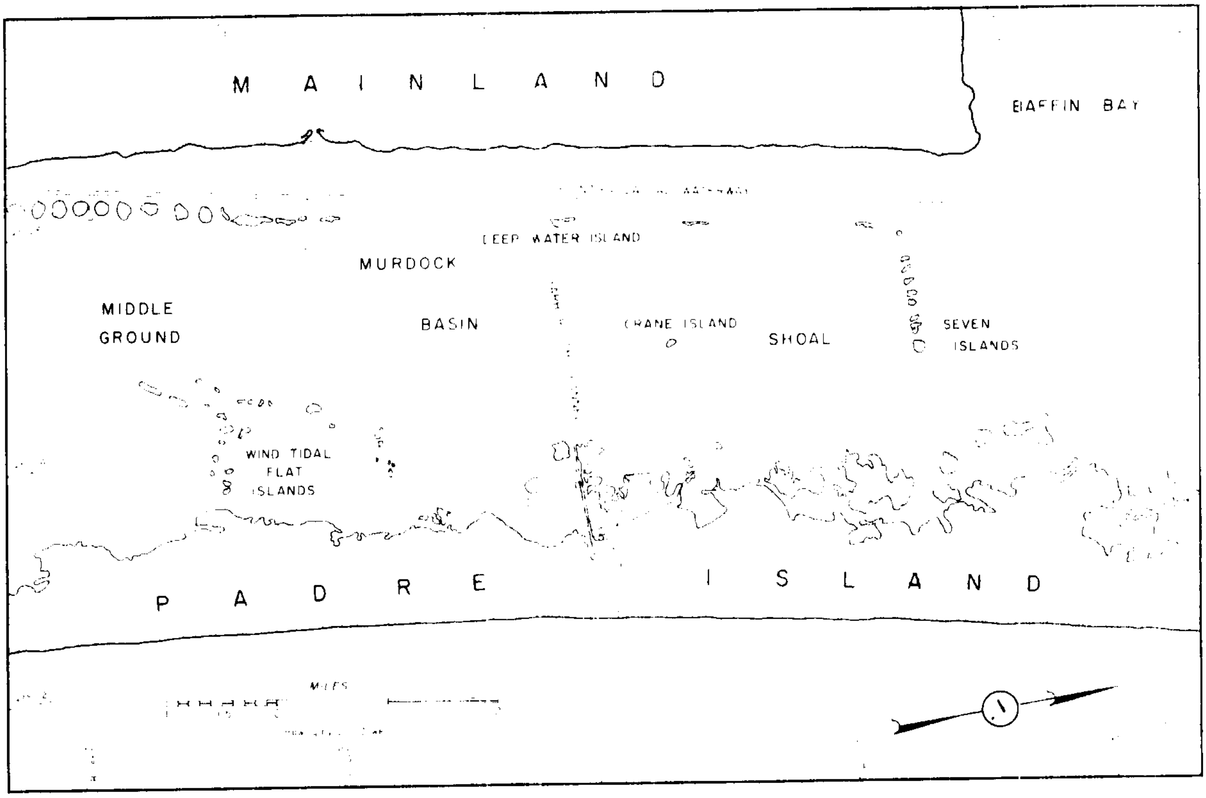
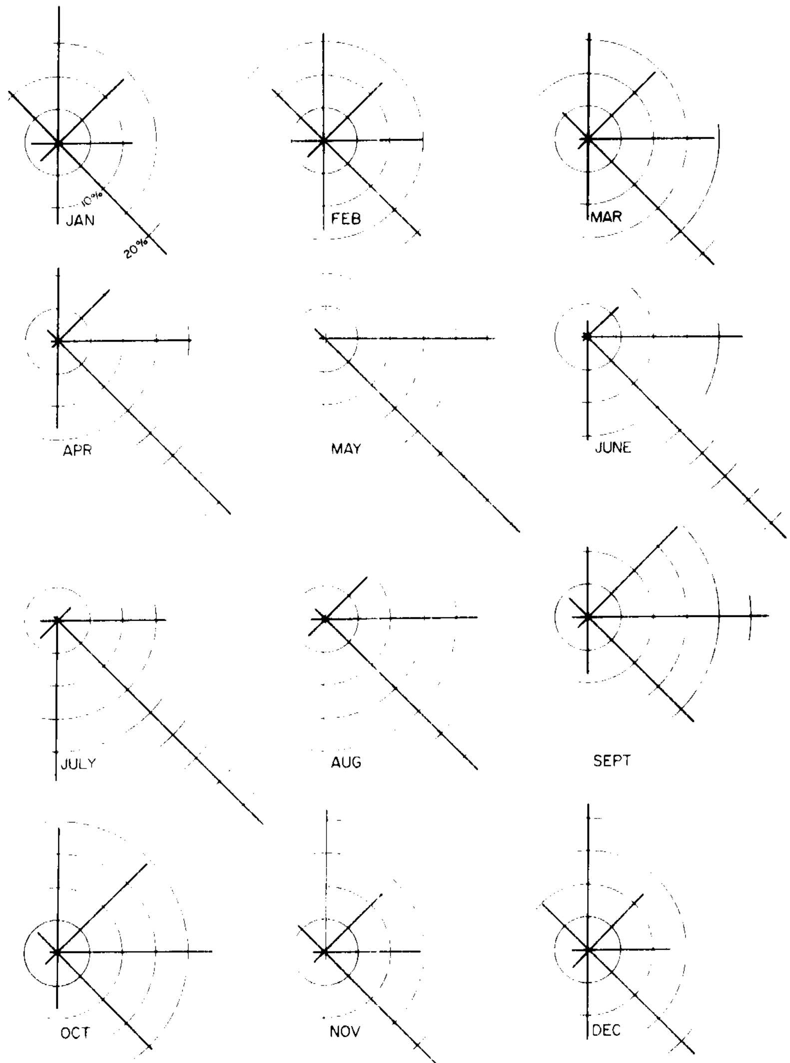


Figure 1. Map of Murdock Basin in Laguna Madre, Texas



% FREQUENCY OF WIND BY DIRECTION AT CORPUS CHRISTI
(1887-1968)

Figure 2.

longshore current erodes sands off the beach and transports them north leaving escarpments along the shore (Figure 3). In the lagoon, winds generate waves which attack the shoreline causing shoals and escarpments on the islands.

Tidal variation in the Gulf is approximately 1.5 feet (0.5 m). Tidal influence in Laguna Madre is minimal because the restricted passes allow little water flow into Laguna Madre; specifically, to the north, Aransas Pass and the restriction of John F. Kennedy Causeway from Corpus Christi Bay into Laguna Madre, and to the south, Mansfield Pass and Brazos Santiago Pass (Figure 4). Little water can move through these passes during tidal fluctuation. Consequently, tidal influences are filtered out. Water level changes in Laguna Madre are attributed to wind setup alone.

ACTIVE DUNE FIELDS

To understand the sediment budget of Laguna Madre and to minimize maintenance problems, the physical processes which introduce sediment into the lagoon, and transport sediment within it should be understood. A major contributor of sediment is the island dune field.

A characteristic geomorphic feature of North Padre Island are the large active dune fields, each covering many square kilometers in aerial extent. The origin and the development of these dune fields do not appear to follow the hurricane mechanism proposed by Boker (1953), Blankenship (1953), or Hayes (1967), but rather are dependent upon the development of an aerodynamically stable chute and on aeolian mechanisms.

The development of dune fields (aeolian fans) progresses through five stages (Figure 5) (Mathewson, et al., 1975). The initial morphologic features of the barrier island include the beach, the foredune ridge, and

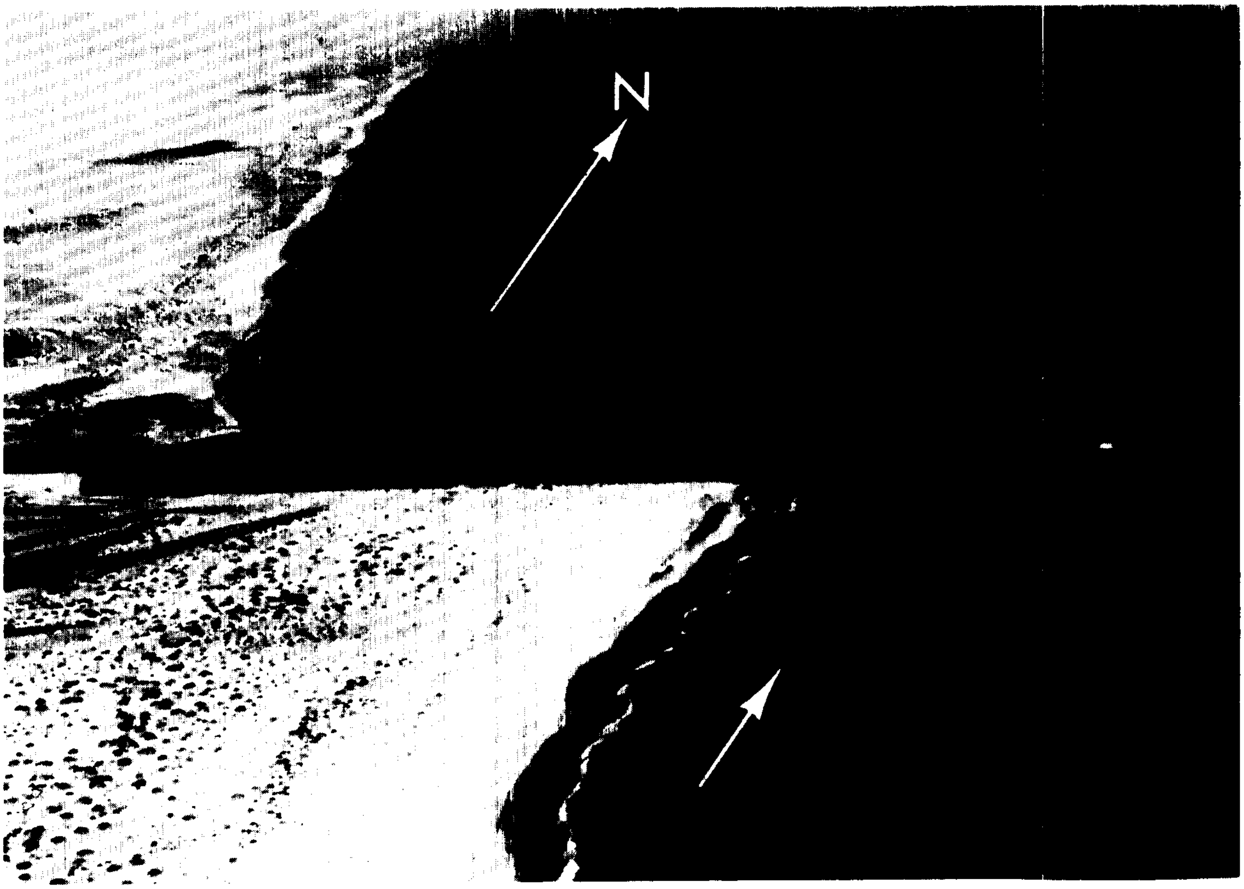


Figure 3. An aerial view looking north of the effects of longshore currents at Mansfield Pass, Texas. Current flow is to the north depositing sediment at the south jetty and eroding as is shown by the direction of the arrows.

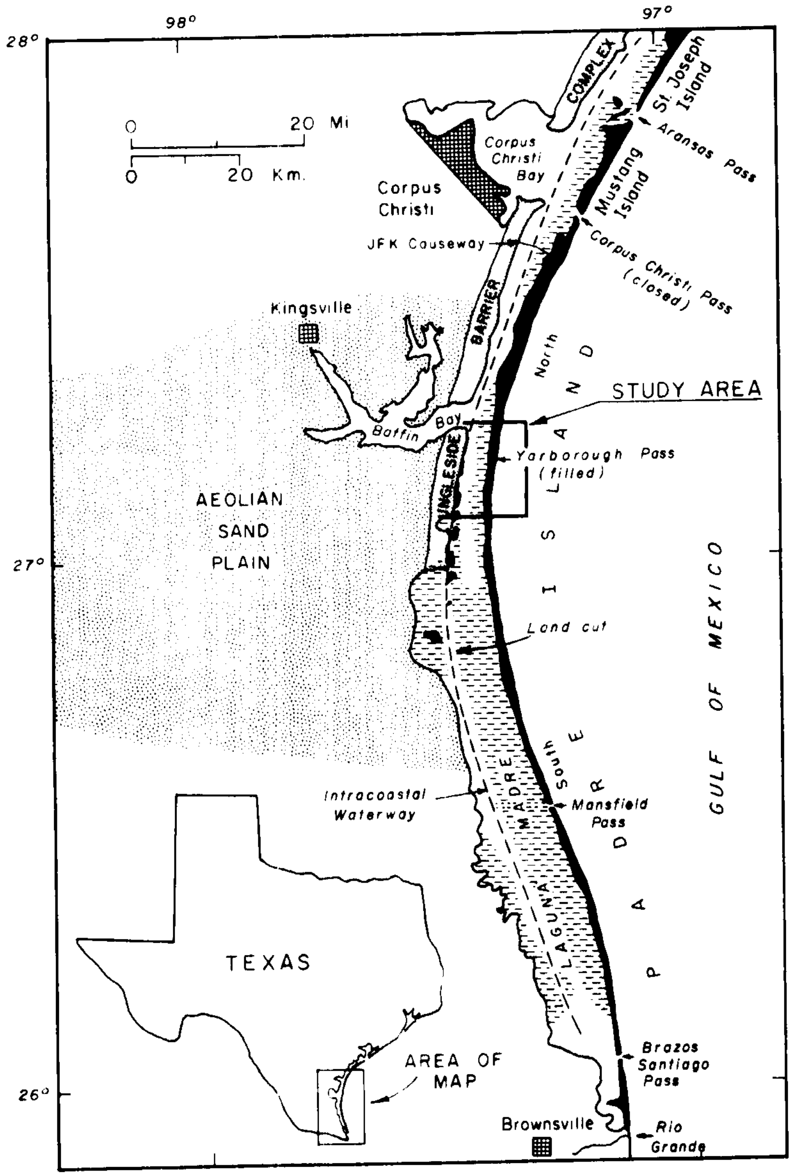


Figure 4. A map showing the geomorphic features of the South Texas coast. The study area is in the vicinity of Yarborough Pass.

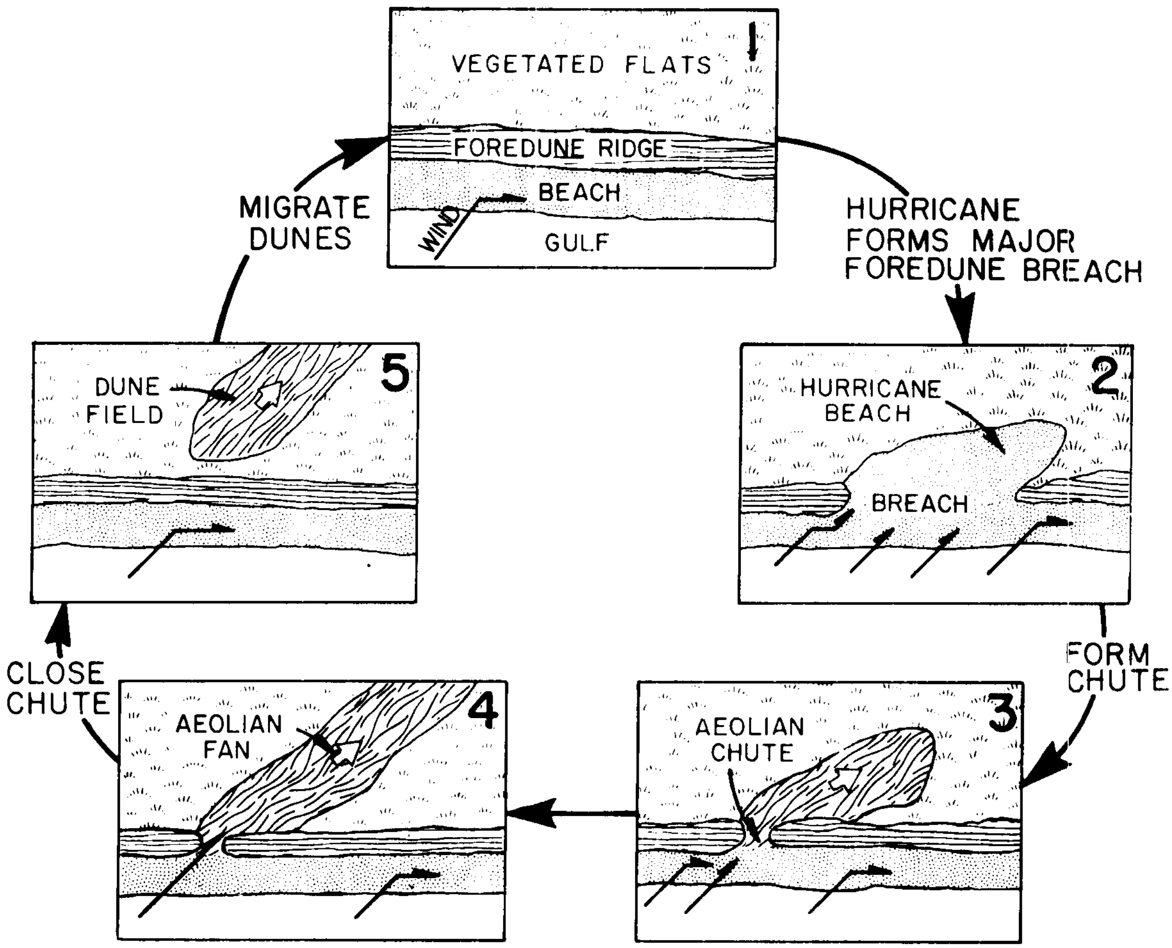


Figure 5. Schematic diagram of the development of the aeolian chute and fan. Initially a hurricane breaches the foredune ridge and forms a hurricane beach ridge (2). The breach gradually heals until the chute forms (3). Continuous sand transport through the chute forms the aeolian fan (4). Once the chute closes the dune field migrates downwind (5).

vegetated flats which grade lagoonward into wind tidal flats. Sediment is deposited on the beach where the onshore prevailing winds sort the sand and transport it across the beach where its movement is deflected northward by the foredune ridge. During hurricanes, storm waves attack and destroy the foredune ridge and generate storm breaches.

Hayes (1967) defines three types of foredune ridge breaches: major hurricane channel breach, minor hurricane channel breach, and the total destruction of the foredune ridge for long distances (1 mile or more). In the case of the major and minor hurricane channels the breach is narrow, and it usually heals quickly when compared to the larger foredune breach. In the area of the larger breach, hurricane waves form a hurricane beach ridge.

The hurricane beach ridge is topographically higher than the surrounding flats and is above the capillary fringe of the island freshwater lens. This higher elevation allows the sand to drain, thus re-vegetation is slow and aeolian processes become a major factor. Reconstruction of the foredune ridge by aeolian processes, as described by Bagnold (1941) and Fisk (1959), closes the major foredune breach except at the southern end where high sediment transport and high wind shear keep the sand from depositing. An aerodynamically stable chute forms at this point, and it continues to feed aeolian sand through the foredune ridge to form an aeolian fan. The chute is generally aligned with the prevailing winds and remains a transport route for windblown sand for extended periods of time.

Eventually, the chute becomes inefficient due to encroachment from the vegetated foredune ridge and is closed. Following the closing of the chute, the source of sediment for the aeolian fan is lost. The fan migrates across the island as a dune field and becomes the back-island dunes.

In 1936, a hurricane formed both a major hurricane channel and a major foredune breach in the area of Yarborough Pass (Figure 6). The 1937 air photograph shows that most of the area had not revegetated. In the 1943 photograph, however, the washover fan has vegetated and most of the foredune ridge has reformed except for the aeolian chute. Between 1943 and 1973, sand was continually added to the aeolian fan through the chute resulting in a lengthening in the downwind direction of the fan. By 1975, the aeolian chute had closed, and the fan had crossed the flats and encroached onto the wind tidal flats. Vegetation is slowly continuing to stabilize the head of the fan. As the head of the fan deflates, the sand migrates onto the wind tidal flats forming the back-island dunes and continues to move lagoonward. With a recurring storm of the intensity of that in 1936, the chute may be re-opened or the dune wall breached initiating the cycle again.

CHANNEL SILTATION

A network of dredged channels, from small boat channels to the Gulf Intracoastal Waterway, has been constructed in Laguna Madre. Many of these channels have a short operational life due to rapid sediment infilling and therefore represent significant maintenance costs and hazards to navigation. In many cases dredge material was placed next to the channel, apparently without regard for the sediment transport processes. Consequently, adjacent dredged material islands are often major contributors of sediment to the channels.

Air photographs taken in 1953, 1960, 1974 show that the net sediment transport in North Laguna Madre is southeastward from dredged material islands in shallow water < 3 feet (< 1 meter) areas and in the wind tidal flats. Islands in deep water > 3 feet (> 1 meter) areas show transport in both a southeastward and northwestward direction (Figure 7).

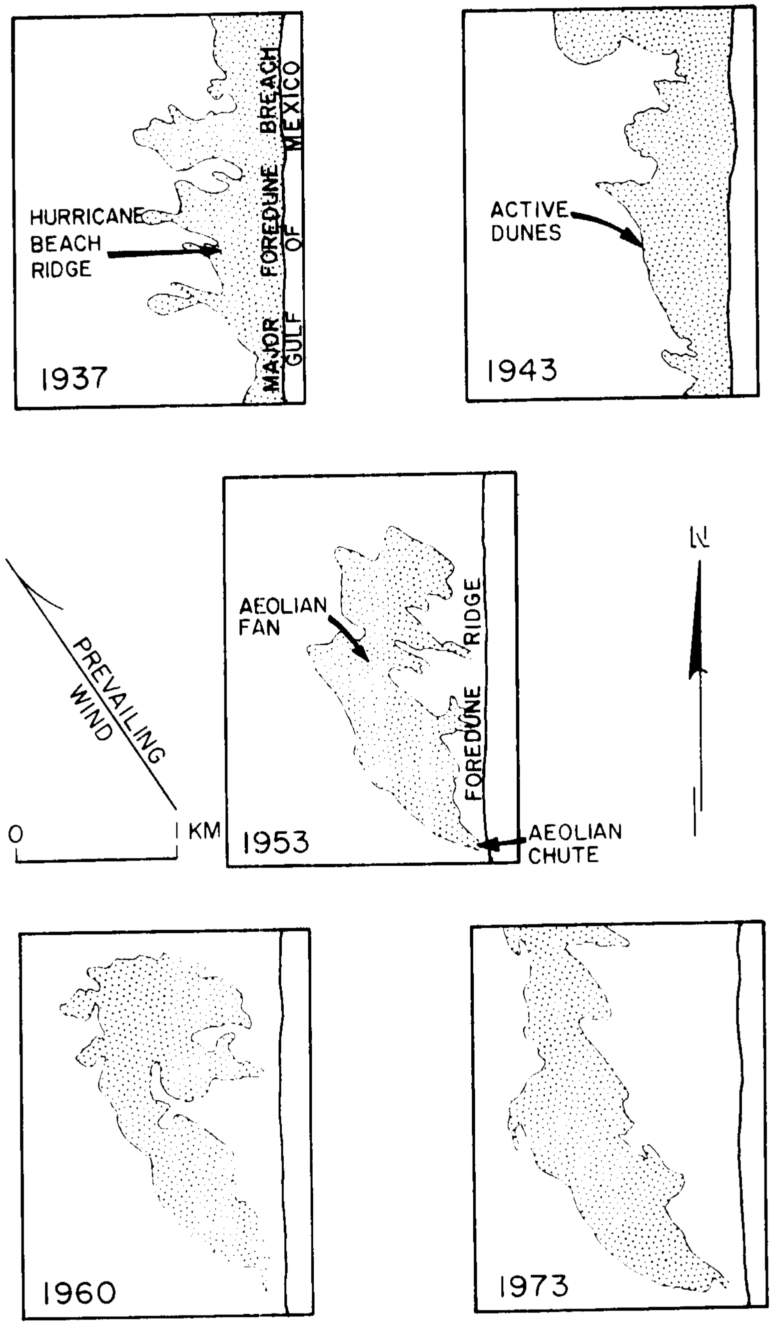


Figure 6. Photomaps of the distribution of unvegetated sand areas subject to aeolian processes. Note the northwestard growth of the aeolian fan from 1953 to 1973, demonstrating that the chute is the active path for aeolian sediment transport.

Net sediment transport directions were determined from observing the morphologic changes of the islands, which are: island elongation, erosion, shoaling, and spit growth. Figure 8 shows "Crane Island" in Laguna Madre, a shallow water island, elongated southeastward with a wave-cut scarp facing northwestward indicating long-term sediment transport to the southeast. Differences in the net sediment transport direction between deep water and shallow water areas appear to be controlled by the regional wind pattern, which in turn controls wave action and water depth. As noted by Price (1952), and Stinson and Clary (1974), the wind in South Texas is subequally divided in velocity, direction, and duration between the strong offshore, longshore "northers" of winter and the prevailing onshore southeasterly winds of summer.

During the summer, the prevailing onshore winds generate a current flowing to the north, driving water off the wind tidal flats and lowering the lagoon water level. With these prevailing southeasterly winds, the sediment transport direction is to the northwest in deep water areas. Dredged material islands on the wind tidal flats are not altered by wave processes because the flats have been blown dry. Also, aeolian processes on the wind tidal flats have little significant effect at this time because the exposed sediments are saturated by the capillary water table. In shoal areas the decreased water depth results in a decreased wave height and erosion is at a minimum. In addition, floating organic matter tends to be washed onto these islands forming floating breakwaters that further reduce erosion.

In the winter, storm winds from the north cause a strong current to the south, raising the water level in the lagoon and inundating the wind tidal flats. Since wave activity is controlled by water depth, erosion

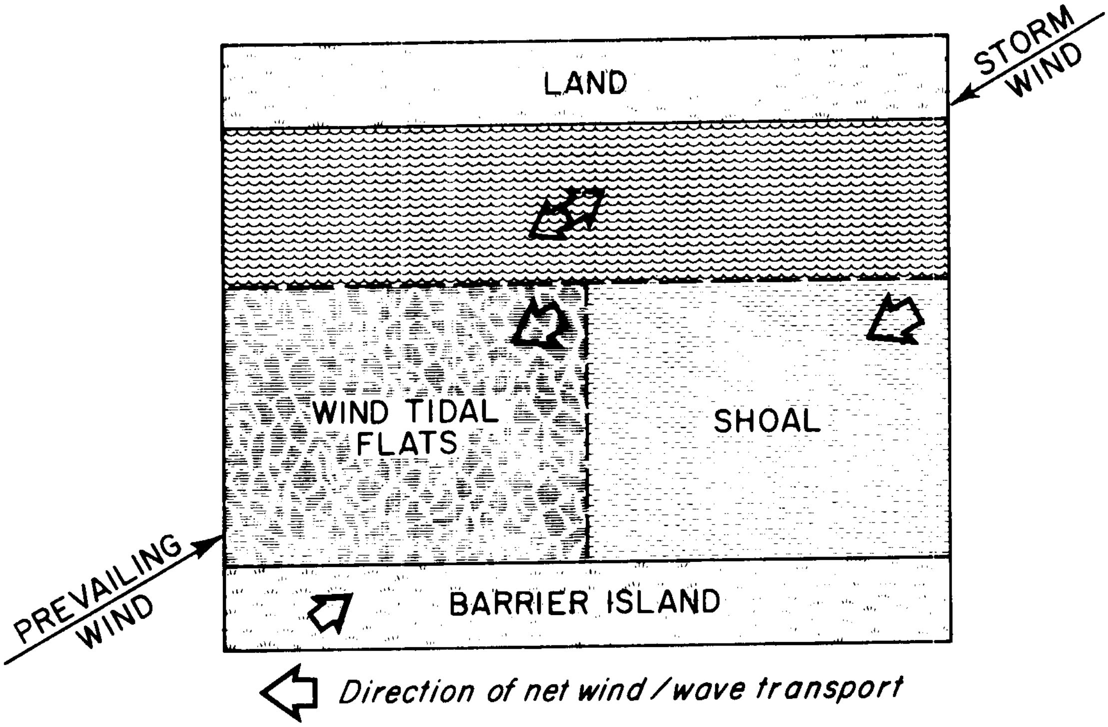


Figure 7. Diagram indicates sediment transport directions in the study area.

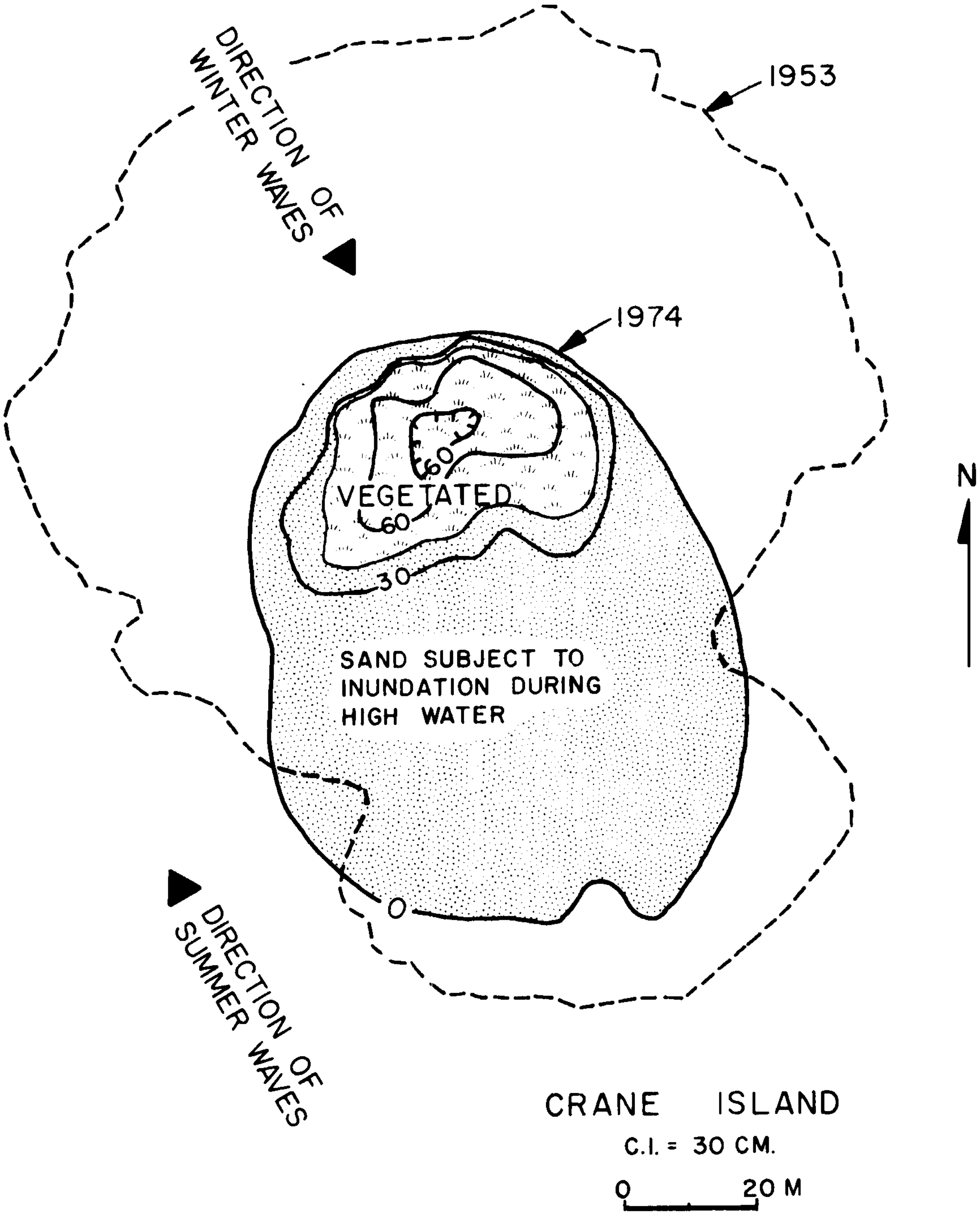


Figure 8. A 1974 topographic map of "Crane Island", a dredged material island in Laguna Madre compared with the island outline soon after dredging in 1953. "Crane Island" is in shallow water and has a net sediment transport toward the southeast.

rates and sediment transport during winter storms are increased. As a result, dominant sediment transport is to the southeast on the wind tidal flats, in the shoal areas and on deepwater islands.

Severe storms and hurricanes appear to have little influence or effect on the erosion of the islands, because the islands are inundated by as much as 6 feet (2 m) of water. As a result, wave erosion is minimal. In addition, the frequency of these events is such that any island modification is soon masked by the daily processes.

Due to the interdependency of water levels and wave energy with the meteorological conditions, placement of dredged material must consider both the average prevailing conditions and the irregular conditions. Historical photographs and maps are a valuable source of information for the determination of long-term sediment transport. They can be used to interpret combined effects of both prevailing and irregular conditions with the geomorphology of the bay. Therefore, if dredged material is placed on the downdrift side of a channel (Figure 9), maintenance costs and navigational hazards would be reduced.

CONCLUSION

Although the hurricane is a significant coastal event, capable of drastically altering the barrier island-lagoon system, this study suggests that long-term seasonal processes play the major role in influencing construction and maintenance along the coast. These processes should be identified and evaluated as a routine part of any site investigation carried out for dredging in the shallow water environment.

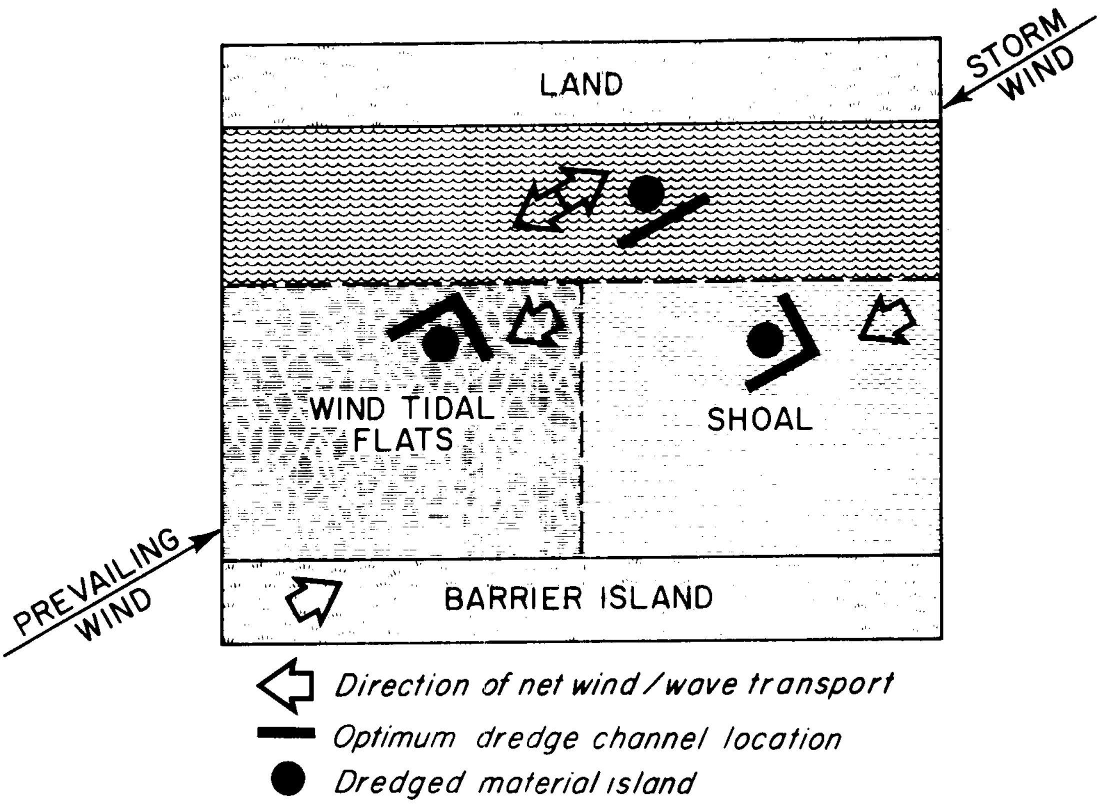


Figure 9. Diagram indicates the proper location of dredged material placement to minimize the return of dredged sediment to the channel.

ACKNOWLEDGMENTS

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A NEW CONCEPT FOR DREDGED MATERIAL DISPOSAL

by

Michael R. Palermo,*
Raymond L. Montgomery

ABSTRACT

Acquisition of suitable land for confined disposal of dredged material has become increasingly difficult due to rising cost and public objection to land use for this purpose. This problem could be minimized if the useful life of disposal areas could be extended, allowing reuse over longer periods. The concept of disposal site reuse involves the reduction in volume and/or actual removal of dredged material from the disposal area for use elsewhere, thereby allowing additional placement of dredged material at the site. Multiple advantages can be realized through site reuse: (a) a permanent reusable site would be provided for maintenance dredging at a centralized location; (b) operation of reusable sites would be environmentally compatible because facilities could be properly planned and engineered, greater control is possible, and site operation is better supervised; (c) valuable resources could be reclaimed from the dredging operation and donated or sold for productive use; and (d) expense and public objection to new disposal areas would be greatly reduced due to reduction in excessive land-use requirements.

For site reuse to be successful, the material must be in a usable condition, potential uses must be identified, and site management must be tailored to meet requirements for continued reuse. Research completed to date has identified methods of separating, drying, and rehandling dredged

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material, legal and policy constraints regarding marketing and disposition of the material, and potential use of dredged material for landfill and construction purposes. The feasibility of site reuse as established through completed and ongoing research must be established by field studies which are currently being initiated. Ultimate widespread use of reusable disposal areas will depend upon future constraints placed on conventional disposal methods and upon economic and environmental considerations.

PREFACE

This paper was prepared for and presented at the Eighth Dredging Seminar in Houston, Texas, on 7 November 1975. The seminar was sponsored by the Center for Dredging Studies, and by the Sea Grant College Program, Texas A&M University.

The work described herein was conducted under the Dredged Material Research Program (DMRP), Environmental Effects Laboratory (EEL), U.S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Mississippi.

The paper was prepared by Mr. Michael R. Palermo, Design and Concept Development Branch, and Mr. Raymond L. Montgomery, Chief, Design and Concept Development Branch. The paper was presented by Mr. Palermo in Houston.

The report was prepared under the general supervision of Dr. John Harrison, Chief, EEL, and Mr. Andrew J. Green, Chief, Environmental Engineering Division, EEL.

Director of WES during the preparation and publication of the paper was COL G.H. Hilt, CE. Technical Director was Mr. F.R. Brown.

INTRODUCTION

1. Millions of cubic yards of sediment must be dredged annually to

maintain navigation channel depths because of the effects of shoaling. The maintenance dredging data shown in Figure 1 provides an indication of the annual quantities of material dredged and the relative importance of the common disposal methods (open-water, confined, and unconfined) in the various geographical regions. The term "undifferentiated" has been used to cover projects where both confined and open-water disposal are practiced and no breakdown of the total quantity was available. As shown in Figure 1, a large percentage of dredged material must be confined in land disposal areas, and each year large amounts of new land are required to accommodate these disposal needs. Because most dredging projects are located in the estuarine zone where there are already excessive and often conflicting land-use requirements, it is doubtful if land use for a form of waste disposal can continue at the present rate.

2. Virtually without exception, the dredged material disposal problem foremost in the minds of the Corps District and Division office personnel contacted during the first phase of the Dredged Material Research Program (DMRP) conducted by the U.S. Army Engineer Waterways Experiment Station (WES) was that of finding available sites for land disposal of dredged material.[1,2] In a number of Corps Districts, important dredging has been delayed because land disposal sites were not available. In other Districts, historical disposal sites are being filled and no new land is available for new containment facilities.

3. Under the DMRP a new dredged material disposal concept--the reusable disposal area--is being investigated. The purposes of this paper are to present this disposal concept and to discuss its current status.

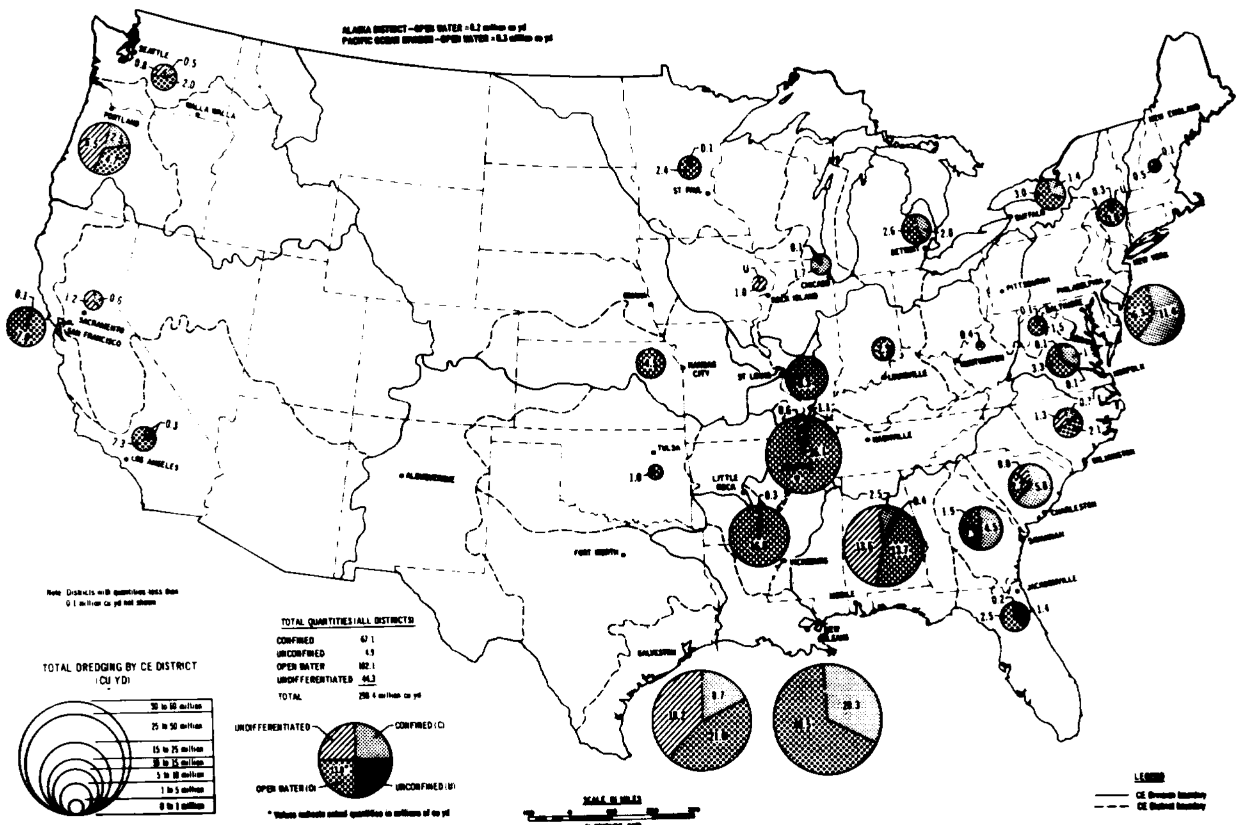


Figure 1. Disposition of dredged material generated in maintenance dredging operations and average annual quantities of material disposed by area by District (1972)

DISPOSAL AREA REUSE CONCEPT

4. The reusable dredged material disposal area would be a collection and processing site where valuable portions of the dredged material would be made available for productive use while unusable material would be treated, if necessary, and disposed of. Methods and procedures would provide for continuous or periodic removal of dredged material for use or storage elsewhere in order to increase the life expectancy of the facility. It might be more appropriate to call the reusable disposal facility a dredged material transfer station where dredged material would be collected, processed, and prepared for transportation to other areas for productive use or disposal.

5. In one sense this concept is not entirely new to Corps dredging activities. A form of the concept has been used to transfer dredged material from transporting vessels (scow or hopper dredge) into a land-transporting system to move the dredged material to land containment facilities. In this case the object was simply to transfer the dredged material from one mode of transportation to another for disposal on land. However, the reusable disposal area concept now being developed in conjunction with the DMRP has broader objectives. The major ones are to minimize the dredged material disposal area land requirements while maintaining environmentally compatible land disposal operations.

6. The advantages of a site that can be reused indefinitely are as follows: (a) permanent sites could be provided convenient to maintenance dredging areas; (b) the expense of and objection to providing new lands for disposal sites are eliminated; (c) construction and landfill materials are made available for productive use; and (d) a reasonable alternative is provided for solving land disposal problems and reducing the excessive use

of valuable lands. From these listed advantages it is obvious that the reusable disposal facility has definite advantages over the conventional land disposal methods used in the past. However, it is not a panacea for land disposal problems. There will be areas where disposal area reuse concepts will not be feasible, but it appears that there are wide areas of potential application.

7. At this time the reusable disposal area is only a concept. But progress has been made toward development of the concept and results from initial field demonstrations should be forthcoming in the near future.

FUNCTIONS OF REUSABLE DISPOSAL FACILITIES

DEGREES OF AREA REUSE

8. The reusable disposal area is essentially a transfer station where dredged material is collected and possibly dewatered, separated, or treated to control contaminants and either used for productive purposes or disposed of.

9. Figure 2 shows a functional diagram for disposal area reuse. As can be seen from this figure, the major factors of a reusable site are dredged material separation (solids and liquid), treatment to control contaminants, and removal of the solids from the site. Such a facility requires complete prior planning and design. All possible elements which must be considered are illustrated in Figure 3.

10. Figures 2 and 3 show the processes necessary to provide the ultimate reusable disposal area. However, all these processes may not be needed in every situation to develop a reusable disposal site. A reusable disposal site is considered to be any site where planning and operations are carried out to extend the life of the site.

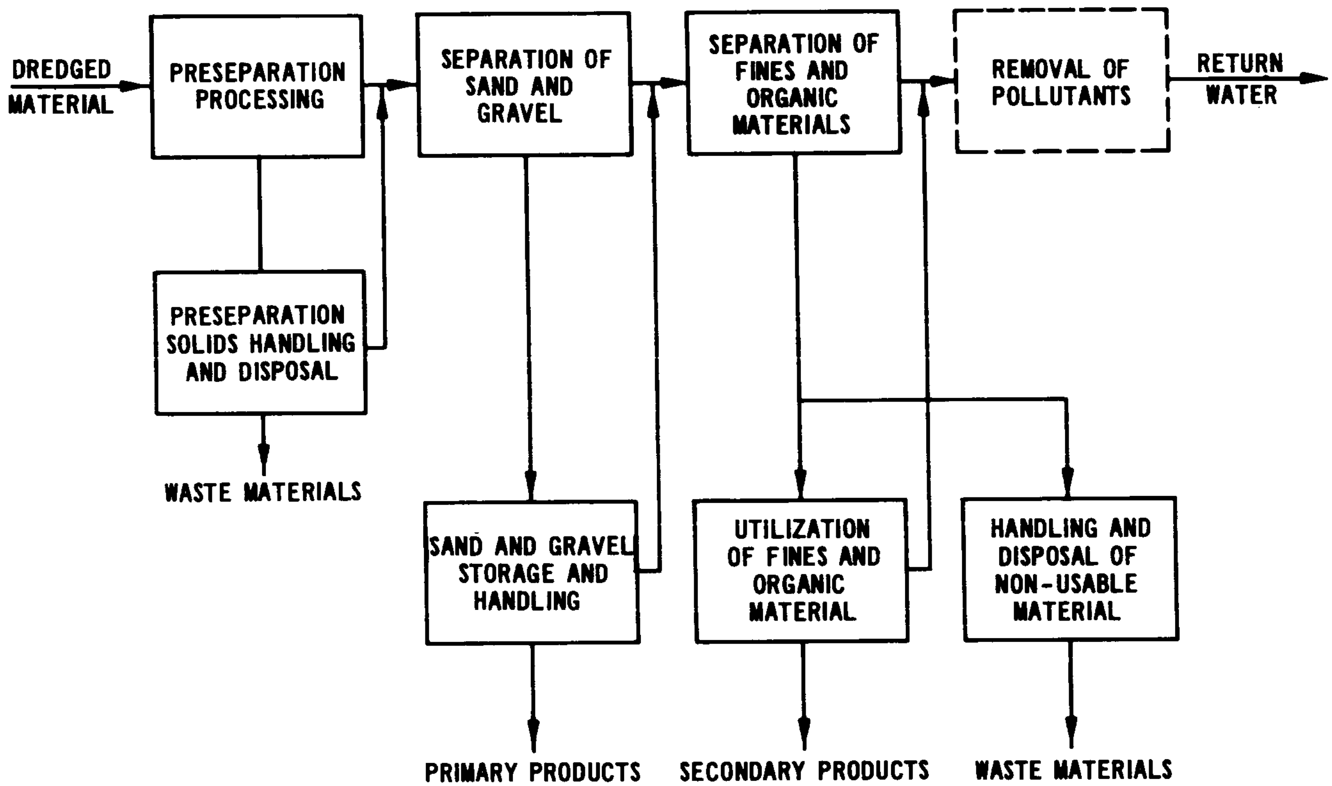


Figure 2. Functional diagram for disposal area

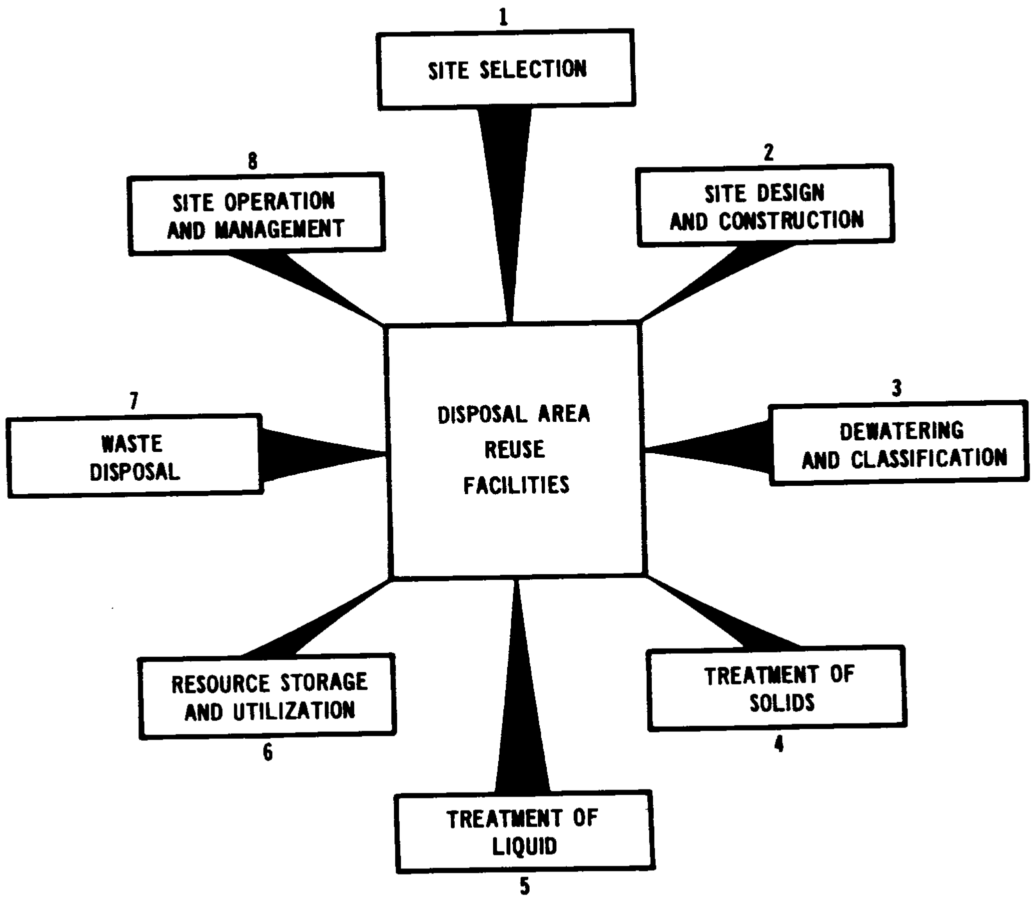


Figure 3. Considerations for area reuse planning and design

11. Conventional disposal practices may be combined with limited processing as shown in Figure 4 to reduce considerably the volume of material requiring disposal.

12. Site reuse in its simplest form involves dewatering dredged material in the containment area through natural processes as shown in Figure 5. Densification of the dredged material and subsequent increased storage volume for future dredged material disposal operations would be provided. This approach may be used in rejuvenating old sites for future use.

13. Regardless of how simple or complex the reusable facility may be, information must be drawn from several research areas of the DMRP to provide the necessary input into the development of the reusable disposal facility.

14. Figure 6 shows the interrelationship among research areas of the DMRP. As shown, the disposal area reuse concept will draw upon the research from four areas and, in turn, provide input into productive uses research.

15. Input from all the research areas shown in Figure 6 will serve to develop a technically sound and environmentally compatible dredged material disposal area that can be reused for long periods.

SEPARATION AND HANDLING

16. If a significant quantity of coarse material is present, it may be advantageous to separate the dredged material into coarse and fine fractions prior to any dewatering effort. Separation can aid in marketing of material for removal off-site, since separated sands and gravels may be utilized with no further processing. Research has been performed to determine the feasibility of separating, drying, and

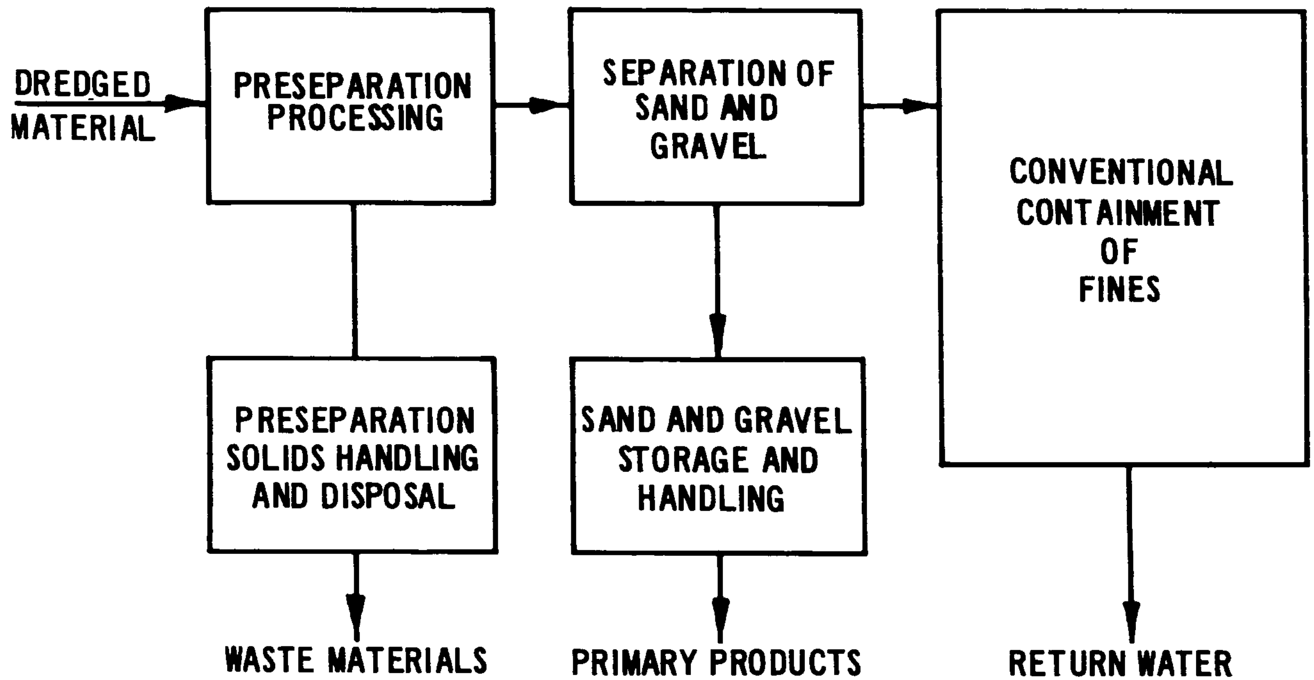


Figure 4. Functional diagram for site reuse through limited handling and processing

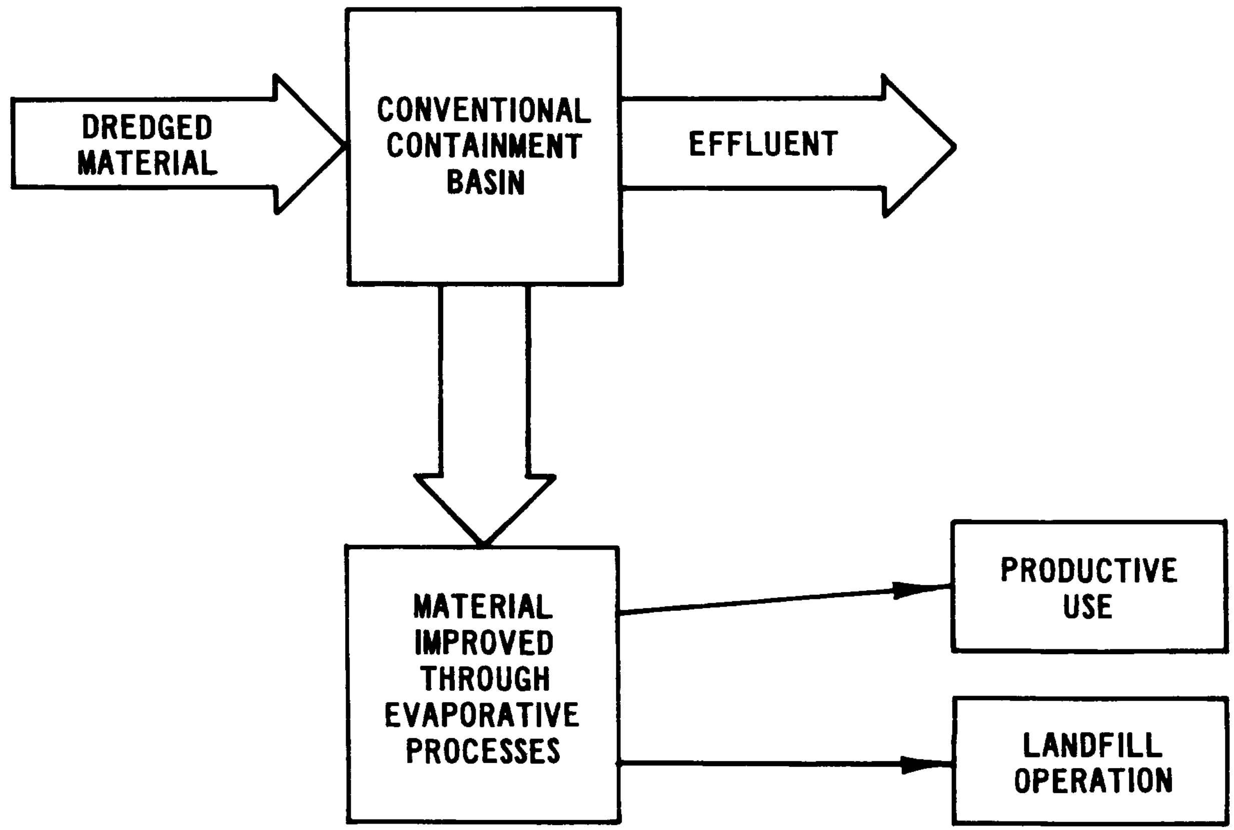


Figure 5. Rejuvenation of conventional disposal sites for reuse

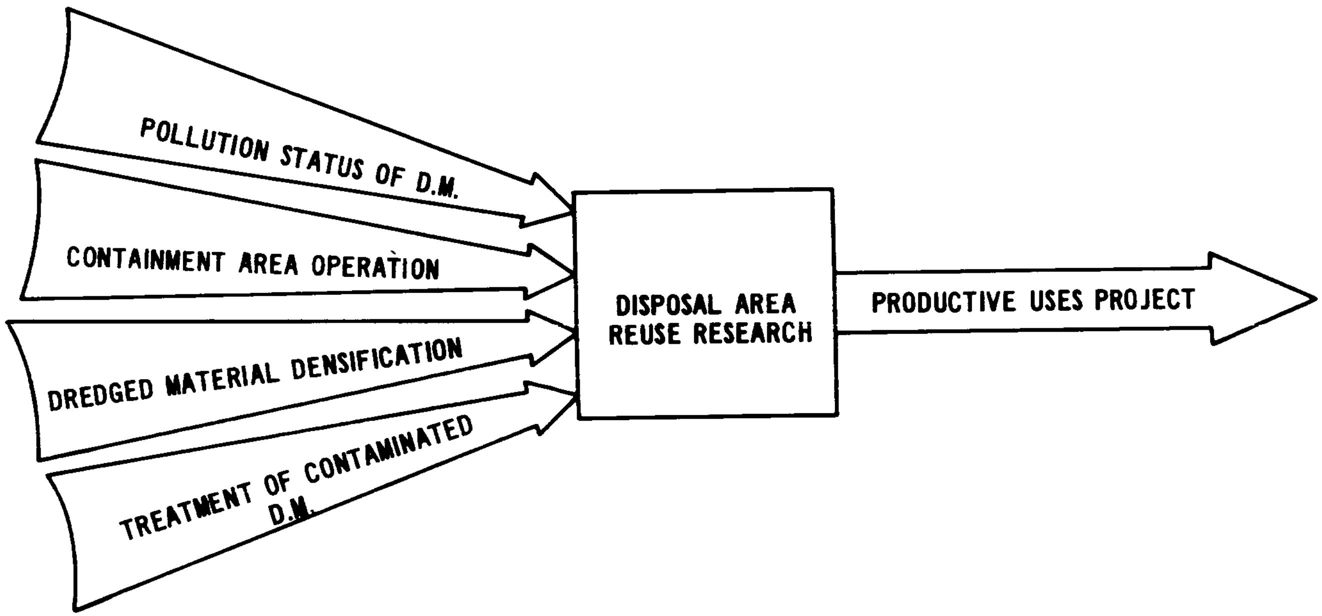


Figure 6. Research relationships for area reuse

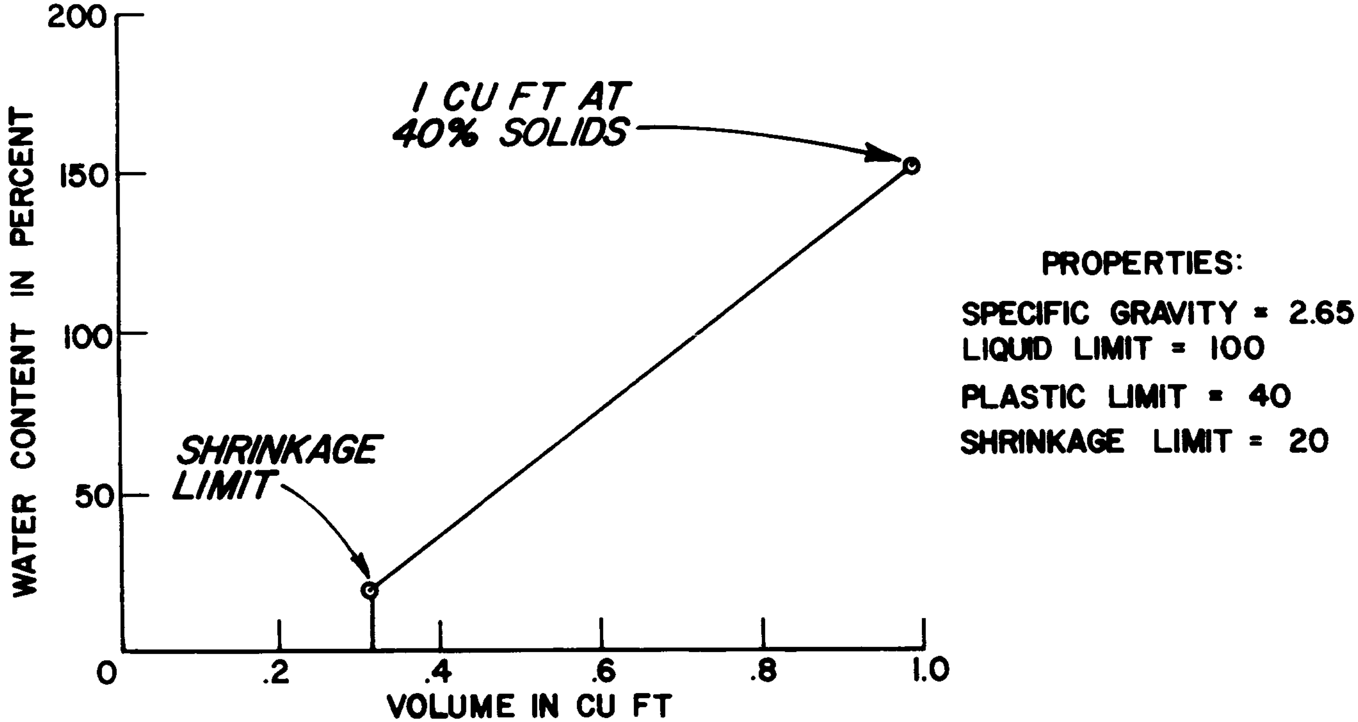
rehandling dredged material to improve its potential as a resource.[3] The use of naturally occurring sedimentation, and mechanical and chemical separation were evaluated. Results of the research indicated that separation of the sand and silt fractions is feasible using commercial equipment and separation basins. It was also found that chemical coagulation can improve clay separation. Other research is being initiated for mechanical separation of fine-grained material using a vacuum filtration system.

DEWATERING

17. The removal of water probably will be essential in the transformation of a dredged material slurry into a usable resource material and is instrumental in the densification of dredged material and extension of disposal area life. Also, dredged material usually must be in an essentially dewatered condition to exhibit desirable properties for removal off-site for productive use. Dewatering is therefore a most important aspect of any disposal area reuse scheme.

18. The fine-grained dredged material presents the difficult problem in this area. Given a set of specific properties, the fine-grained material will decrease in volume in proportion to the amount of water removed up to a limiting value (the shrinkage limit). This relationship is shown for an idealized fine-grained dredged material in Figure 7. The usual practice followed at most disposal areas allows natural evaporative processes to dry the material between dredging phases.

19. A major problem here is the fact that mother nature tends to stand in the way. When dredged material is placed in a diked area, evaporation begins immediately. Unfortunately, with most dredged material, the evaporation occurring immediately after the free water is decanted results in formation of a dried crust that effectively retards evaporation



Figured 7. Volume and water content relationship for fine-grained dredged material

from underlying layers. The upper few inches may approach the shrinkage limit while material below is still at an extremely high water content. If dredged material is repeatedly deposited, the site is filled by small zones of inefficient storage (wet material) as illustrated in Figure 8. The inefficient zones not only waste valuable capacity but limit possible uses of the site after project completion.

20. Dredged material dewatering and densification are being addressed by another research effort under the DMRP. The present state of the art regarding dewatering has been confined to conventional soil mechanics practice for excavations and construction dewatering where rapid dewatering is desired and the areas and volumes involved are usually small. The problem encountered in dealing with dredged material is somewhat different. Here, long periods of time, many months in most cases, can be used for dewatering, and the areas to be dewatered are sometimes hundreds of acres. Cost is the overriding factor. The methods employed can be slow, but they must be inexpensive.

21. One method being evaluated by the DMRP involves a crust management concept and has direct application to area reuse because of rehandling aspects involved. Figure 9 illustrates how crust management might be used in rejuvenating a filled disposal area. The dry surface crust is removed and stacked to one side within the disposal area, exposing the wet material below to natural drying processes. The surcharge effect of the stacked crust material displaces wet material below it and induces consolidation in both dredged material and underlying foundation. Crust again forms on the exposed wet material, which is subsequently removed. After repetitive removals the result is a fill section of stable material and a disposal area that can be reused. The dredged material dewatered

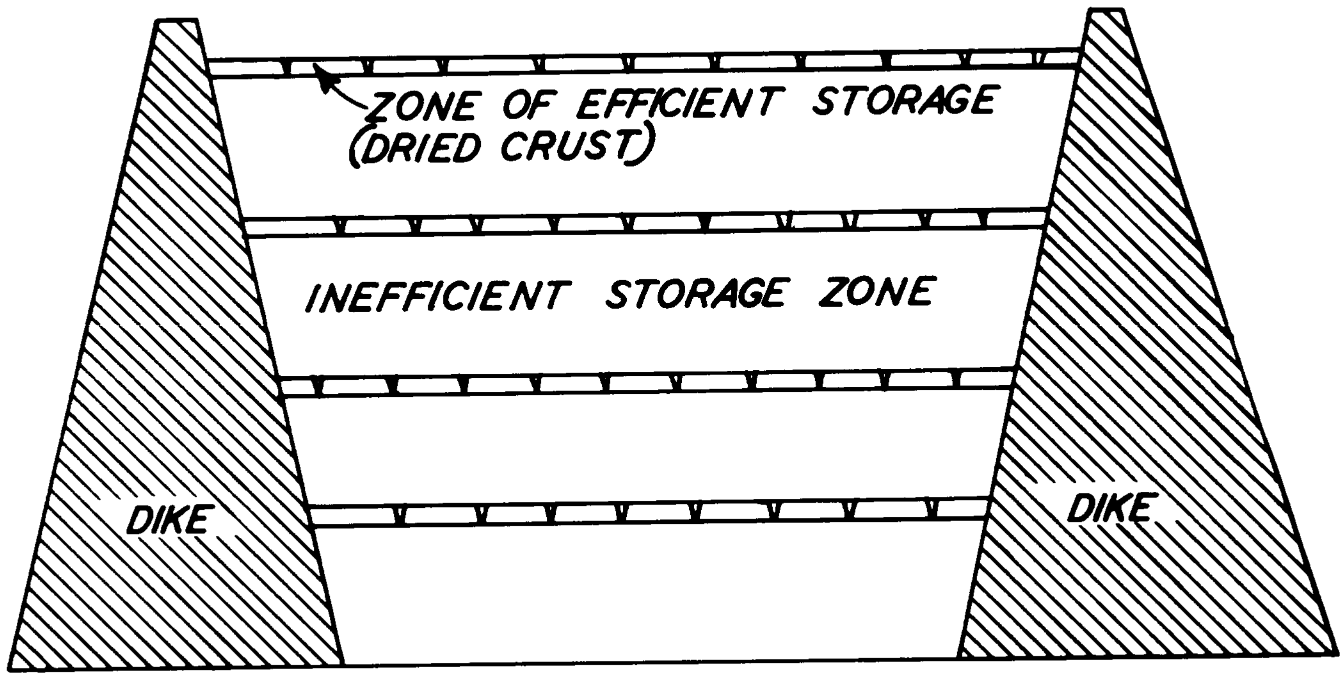


Figure 8. Crust formation in a diked disposal area

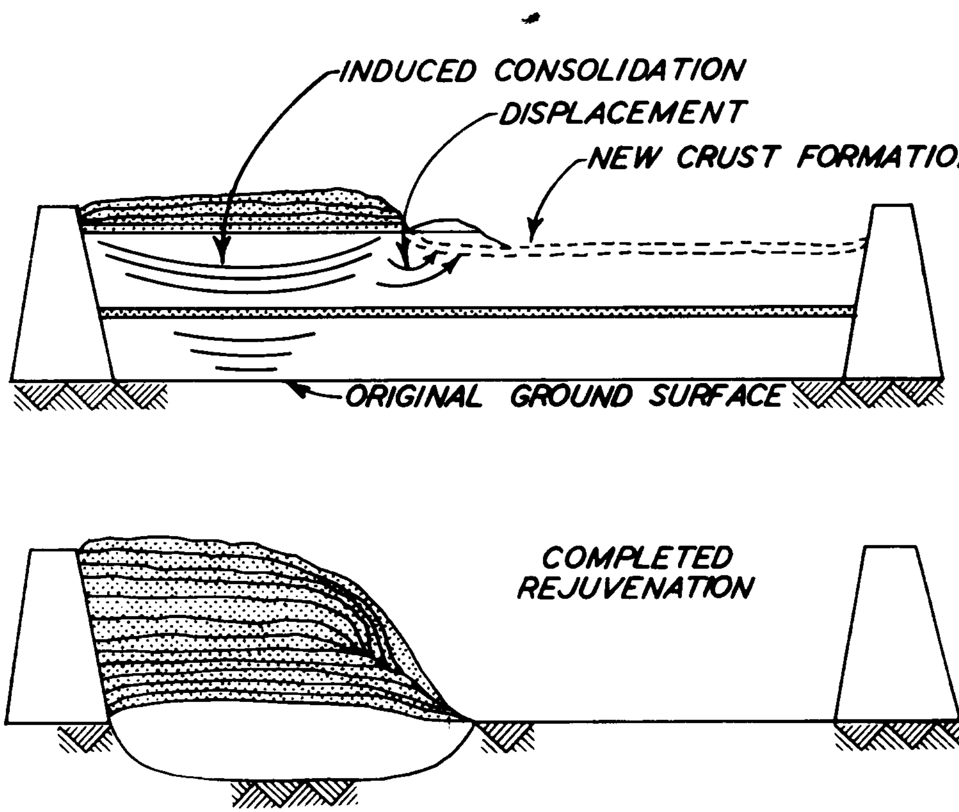


Figure 9. Site rejunavention through crust management

by this technique is much more attractive for use off-site as landfill material or for other productive use.

TREATMENT OF CONTAMINATED MATERIAL

22. Many of the uses for dredged material removed from reusable disposal areas require that it be relatively free from contaminants. Therefore, some treatment of the material itself and effluent water may be a required operation at reusable areas.

23. Contaminants found in dredged material are usually identical with those present in domestic and/or industrial wastewaters. However, treatment processes may be substantially different due to the variable nature of dredged material and the unusually high percentage of solids as compared with most wastewaters. The DMRP is investigating the character of contaminants and methods of treatment for dredged material both during and after disposal. The information gained through treatment research will be directly applicable to the dewatered effluent and solids removed from reusable disposal areas.

DISTRICT INPUT

24. The reusable disposal area concepts are being developed to meet the needs of the Corps Districts. A study team is currently visiting selected Corps Districts to gather information regarding their interest, needs, and comments on this new approach to dredged material disposal and to identify potential field demonstration sites (Figure 10). The Districts will play a significant role in the development of viable concepts for disposal area reuse. For such a concept to be implemented, it is likely that many of the Corps Districts will have to modify their philosophy toward the disposal of dredged material. Considerably more planning, design, and management will be required to implement reusable

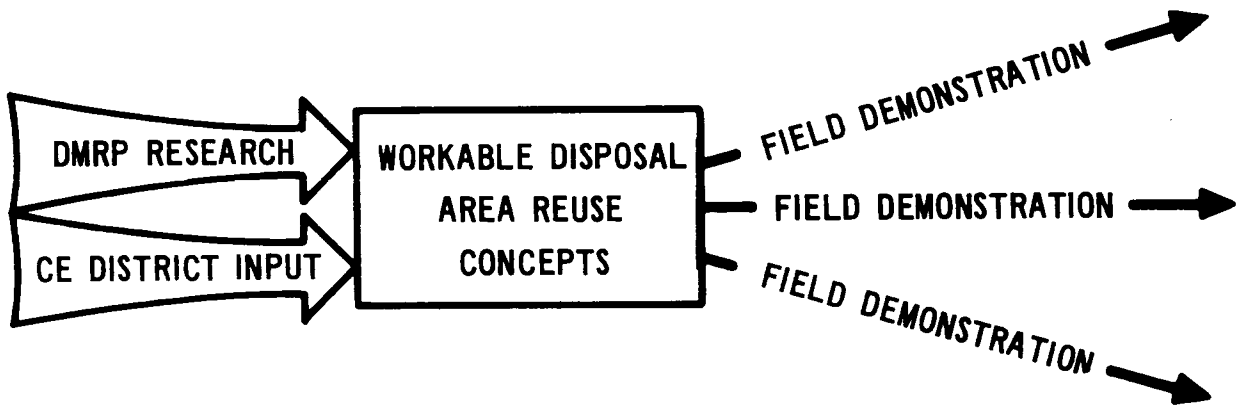


Figure 10. Survey of districts for needs and areas of potential applications of reusable dredged material disposal sites

disposal areas. However, in view of current shortages of suitable acreage for disposal, high construction costs, and public objection to conventional disposal, the reusable area concept appears to be an attractive land disposal alternative. It is time that positive steps be taken to solve land disposal problems rather than rely on past practices that have only postponed the problems for a few years.

USE AND DISPOSAL OF PROCESSED DREDGED MATERIAL

25. A major consideration of the area reuse concept is the use or disposal of materials necessary to permit reuse of the facility. The reusable area may be called a reusable dredged material collection and treatment facility as shown in Figure 11. This figure shows four alternatives for disposal of solids from dredged material processed in the facility. These are reasonable alternatives for maintaining the dredged material capacity of the facility for future dredging operations. But use of these alternatives will depend on the characteristics of the solid fraction of the dredged material processed.

PRODUCTIVE USES

26. Landfill and construction material. The most obvious use of the dried material is for landfill and construction purposes. In many urbanized areas there is a severe shortage of suitable landfill and construction material. Completed research has related the regional requirements for landfill to the availability of dredged material.[4] The types of landfill projects evaluated are shown in Table 1 and are divided into the four main categories of resource, environmental, economic, and urban needs. Contacts were made through regional planning groups, chambers of commerce, port authorities, state and local government agencies, and similar organizations.

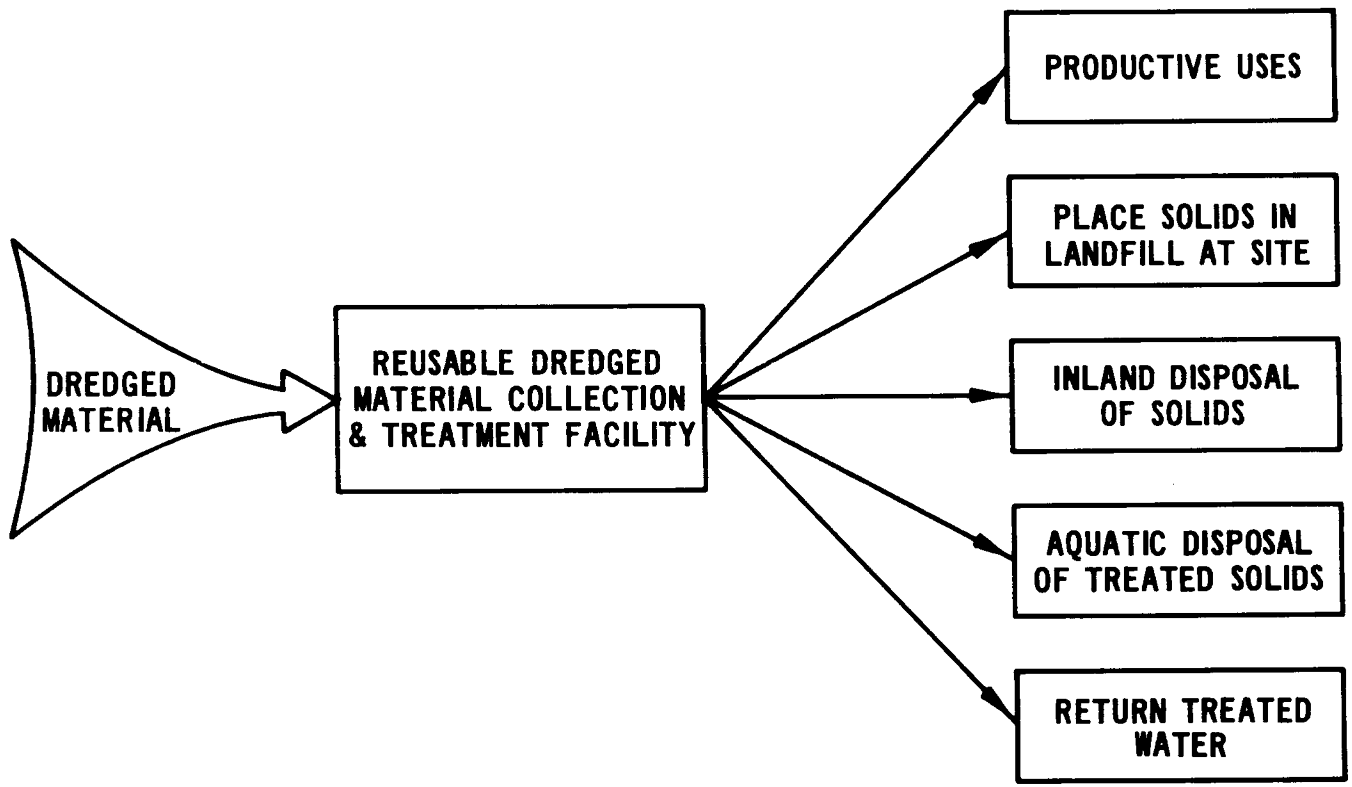


Figure 11. Flow diagram for disposal area reuse

TABLE 1. LAND USE DEVELOPMENTS

URBAN	ECONOMIC
Residential; Housing	Industrial
Commercial	Rail; Rapid Transit
Resorts; Commercial Camps	Harbors; Ports
	Highways
	Utilities
ENVIRONMENTAL	**RESOURCE**
Wildlife Refuges	Artificial Islands
Marine Nurseries	Agricultural/Grazing Land
Beach Nourishment	Forestry
Public Parks and Recreation	Land Reclamation
Marshland Management	Sand and Gravel
Other Landfills	Material Stockpiles
Flood Plain Control/Levees	

Evaluations were made on a regional basis, using coastal zone patterns as shown in Figure 12. General trends for all four categories indicated a high demand for land fill requirements in coastal areas and a decreasing demand inland. The total demand for dredged material for landfill use was in excess of available material from dredging activities. However, use of dredged material as landfill will depend upon convincing the state and local agencies involved that the material can be suitable for this purpose. Use of terms such as muck, slurry, mud, or spoil to describe dredged material has resulted in negative opinions regarding its potential value as a resource. With the possible exception of some purely industrial sediments, dredged material can be considered as soil at an abnormally high water content. Once dewatered, dredged material exhibits engineering properties similar to in situ soils. To prove this, an engineering characteristics study was performed by WES to determine such properties of dewatered dredged material as shear strength, density, permeability, and consolidation characteristics.[5] It was concluded that most dredged material when adequately dewatered is acceptable landfill material.

27. Other productive uses off-site. Productive use of dredged material off-site could contribute to the possible removal of material and restoration of capacity in disposal areas. The constituents of many types of dredged material provide most of the needed assets of good topsoil. Therefore, use of the material as an agricultural enhancement is being evaluated as part of the DMRP's Productive Uses Project. Other possibilities, including restoration of strip-mined areas and pits, are being considered along with transport considerations.

28. Habitat development. The use of dredged material for wildlife habitat development and marsh creation is an environmentally attractive

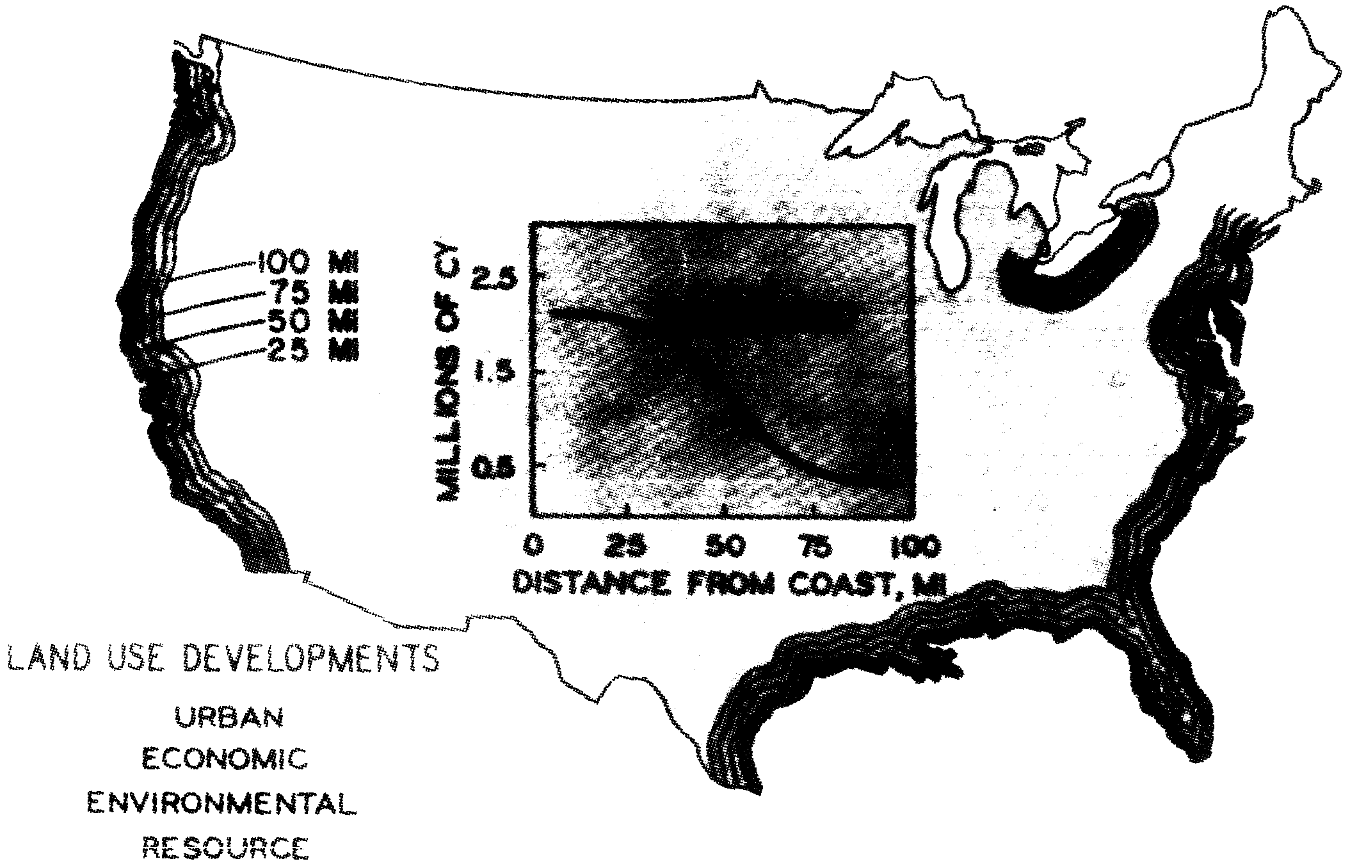


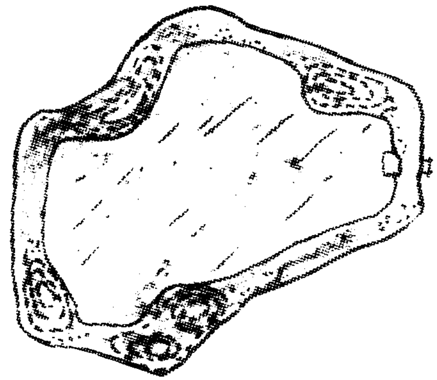
Figure 12. Nationwide landfill and construction material needs

disposal alternative. However, many technical problems relating to confinement of the dredged material and achieving stable tidal elevations are caused in part by the use of slurry for the substrate. The placement of the dewatered material would result in more stable elevations and would require erosion control measures but no confinement structure. Capacity would be restored to existing disposal areas, and encroachment on these valuable lands due to new disposal area requirements would be eliminated.

ON-SITE PLACEMENT OF SOLIDS

29. On-site landfill. Although the optimum area reuse schemes involve removal of the material from the site, the useful life of disposal areas can be greatly increased without actual removal of the material. In addition to required dewatering, other actions can be taken to substantially densify the dredged material mass within the disposal area. Through proper crust management (see Figure 9), the material can be densified and can be used to create on-site landfills. Not only is the material densified, but the potential use of the site is greatly enhanced due to increased bearing capacity. Another alternative is the placement of material within the right-of-way or easement but outside of the diked area. In this way the expense of diking at new sites could be limited to smaller areas sized for effluent quality only and not for total storage capacity. This alternative requires proper crust management, i.e. periodic removal of the dried material from the containment area to the adjacent landfill, allowing the containment area to be reused. If right-of-way outside the diked area at older sites is not available, the landfill can be placed within the dikes, as shown in Figure 9.

30. Mounding. An interesting variation of this concept is shown in Figure 13. Completed research on disposal site landscaping includes



MOUNDING

GUIDELINES AND SPECIFICATIONS:

1. BREAK UP THE RIGID ELEVATION VIEW OF THE FACILITY.
2. SPACING AND HEIGHTS VARIED AND GROUPED.
3. GROUP NEAR THE INTERSECTIONS OF THE PERIMETER STRUCTURE.

Figure 13. Landscape mounding at dredged material disposal areas (Roy Mann Associates, Inc.)

concepts for landfill moundings created by dredged material taken from the site interior.[6] Not only is the capacity of the site increased by the mound creation, but the site can be made more aesthetically pleasing and environmentally compatible and therefore more acceptable to adjacent land owners. The use of such mounding tends to blend the site into its surroundings so that it tends to lose its disposal area identity.

AQUATIC OR UPLAND DISPOSAL

31. The disposition of unusable portions of dredged material and effluent water is a significant aspect of site reuse. Contaminated effluent water can be simply returned to the stream following required treatment. However, the unusable solids resulting from any treatment process must be handled and eventually disposed of. After treatment to control contaminants, this material can possibly be placed in aquatic disposal sites or transported to less expensive inland disposal areas. This same principle can be appplied to unusable solids in slurry form not easily suited to dewatering. The material could be treated at the reusable disposal area and then disposed of in aquatic or upland areas. A major consideration with this concept is the feasibility of transport by pipeline over long distance.

ACTIVE FIELD STUDY

32. Completed research has shown the disposal area reuse concept to be feasible, and input from the Corps Districts should provide added workability to the concept. But these concepts must be proven in the field before any widespread use and benefits can be achieved. A field demonstration of inexpensive dewatering/densification of dredged material and possible subsequent area reuse is under way in the U.S. Army Engineer District, Mobile.

33. The Mobile District uses two diked disposal areas on Blakeley Island adjacent to the Mobile River. These sites are used for disposal of fine-grained materials that are carried in a colloidal state in the fresh waters of the Mobile River and Chickasaw Creek, but upon reaching the saltwater interface, tend to precipitate into a dark gray to black sediment. After decantation in the diked areas, the dredged material takes on the appearance and consistency of heavy axle grease.

34. One alternative in the Mobile District's long-range plan included a large expansion of diked areas onto adjacent marshland, but this alternative was abandoned due to environmental constraints. The sites have a remaining capacity of only two years dredging, but must be used for all future work in the area. Therefore, a real need for dredged material densification and area reuse principles exists.

35. The field study will involve efforts to drain the upper Blakeley Island site and evaluate field results with prior laboratory predictive work. Consolidation will be induced within the dredged material and plans formulated for later removal of dewatered material and restoration of the site storage.

36. The dewatering scheme will employ open ditches constructed by both conventional equipment and by the use of the Riverine Utility Craft (RUC), a special-purpose vehicle designed for the U.S. Navy. A conceptual view of the field study is shown in Figure 14. The RUC employs twin helical screws as a means of propulsion, and ditches are created in soft material after several passes of the vehicle in the same path. The relative ditching performance of the equipment will be evaluated along with comparative benefits gained from the dewatering/densification. Effluent water quality will also be monitored.

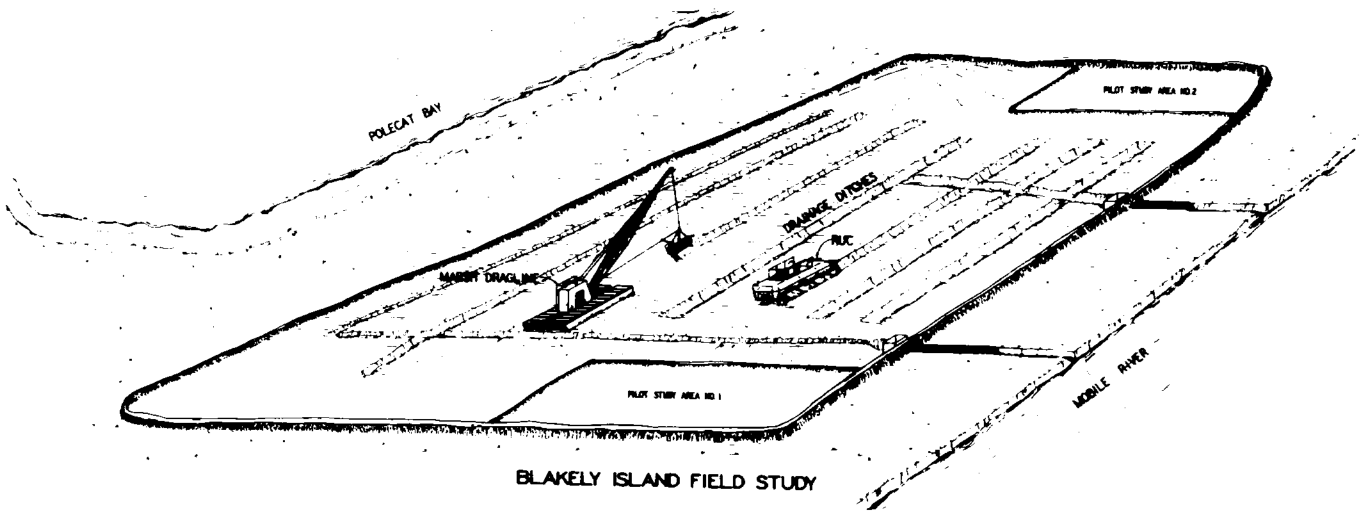


Figure 14. Conceptual view of dewatering operations at the Blakely Island field study site (Mobile District, CE)

37. Sampling was performed at selected locations at the upper disposal area as shown in Figure 15. A comprehensive laboratory-testing program will determine soil conditions, volume-density relationships, and consolidation characteristics. Periodic groundwater measurements at observation wells located throughout the site will evaluate efficiency of the ditching scheme for dewatering. Surveys will determine volumetric changes of the material and benefits gained by densification.

LEGAL AND ECONOMIC CONSIDERATIONS

LEGAL ASPECTS

38. The Corps is usually granted use of real estate for disposal through sponsorship by local interest. Actual ownership of the areas can be held by the Corps, local or State governments, or, in some cases, private concerns. Legal questions arise as to the status and ownership of dredged material placed in these areas, and the legality of its removal and use. A comprehensive study was performed to determine any legal, policy, or institutional constraints associated with dredged material marketing and land enhancement.[7] It was found that, provided the material is environmentally safe when it is donated or sold, there are few hard and fast legal prohibitions against the productive use of dredged material. However, there are a number of both Federal and State laws dealing with water quality, land use, and wetland protection that contain expressions of policy that will restrict temporary storage and some beneficial uses of dredged material.

ECONOMIC CONSIDERATIONS

39. The concept of reusable disposal areas will gain widespread acceptance only after economic feasibility is established. Many factors must be considered in evaluating the economic comparisons between

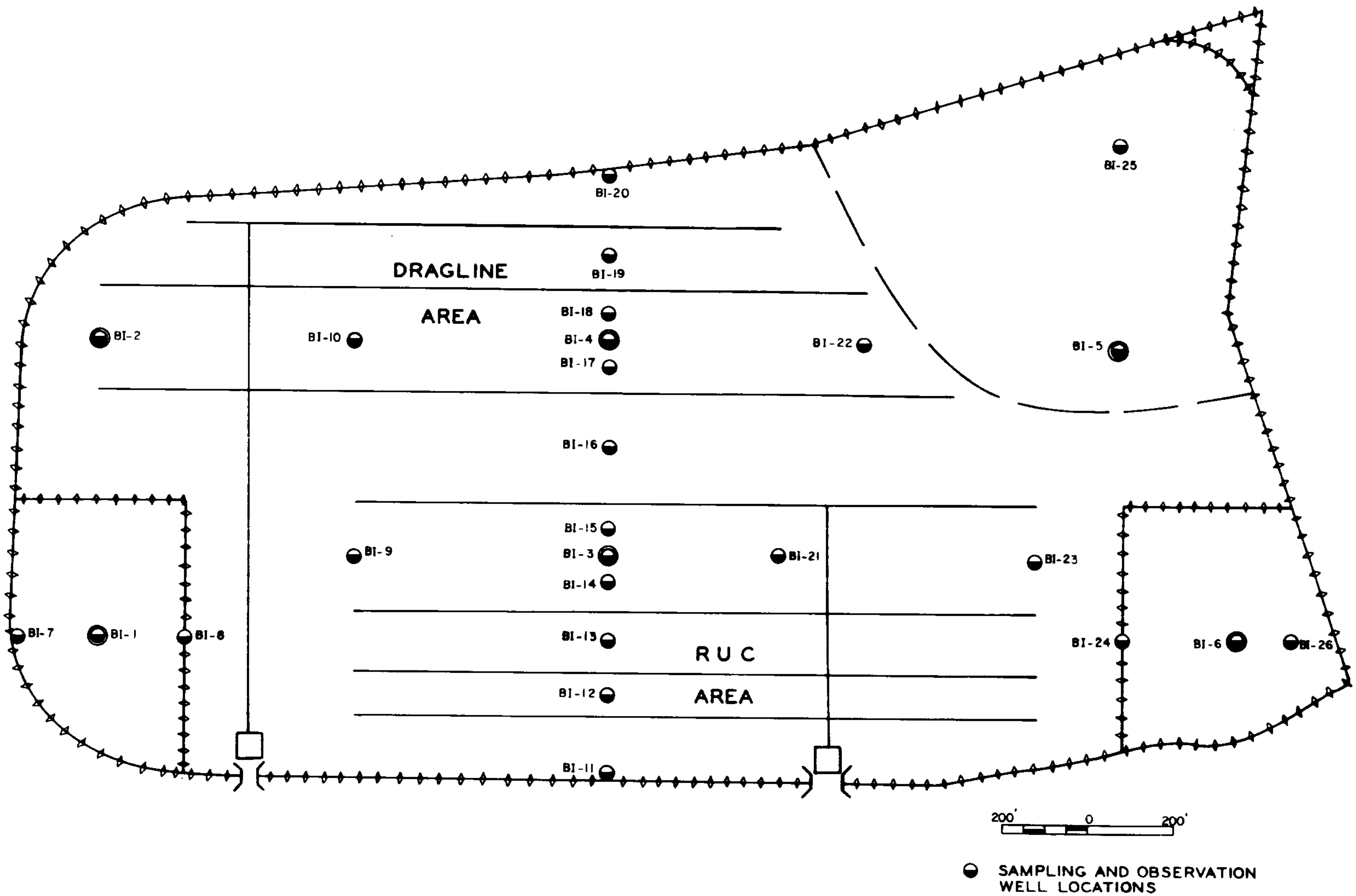


Figure 15. Blakely Island field study site plan

conventional disposal and use of reusable disposal areas. Taken at face value, the costs involved in dewatering, densification, and rehandling material for removal off-site seem much higher than conventional disposal practices. However, many aspects of site reuse tend to defray added expense and may result in area reuse being more economical on a unit basis than continued conventional disposal. Personnel from the U.S. Army Engineer District, Philadelphia, estimated that removal of 1 cu yd of dredged material fron an existing site results in a savings of $0.65, considering costs of land and dike construction.* Increasing scarcity of available land in urban areas and economic trends would cause the potential savings to increase with time. The Philadelphia District has proven that site reuse concepts can be economically feasible through a program of dredged material sales.* Table 2 summarizes the results of the Philadelphia program over a period of two years. Not only did the District realize significant savings through restoration of site capacity, but considerable income was gained through the actual sale of material (up to $0.82 per cubic yard).

40. Other economic benefits derived through area reuse are difficult to estimate in the general case. These include savings in dredging costs by using existing sites convenient to the operation, income derived through sale of resources, economic benefits resulting from productive uses of dredged material, and prevention of environmental degradation through improved design and operation of the disposal areas.

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* U.S. Army Engineer District, Philadelphia, CE, "Sale of Fill Material - Sand and Gravel from Disposal Areas," personal communication, Dec. 1974.

TABLE 2. SALE OF FILL MATERIAL FROM DISPOSAL AREAS

(Philadelphia District)

DISPOSAL AREA	BID/CY	CUBIC YARDS	DATE AWARDED
Pedricktown	$.11	300,000	Oct 72
National Park	.11	10,000	Jul 73
National Park	.12	300,000	Jul 73
Fort Mifflen	.25	150,000	Jan 73
Fort Mifflen	.82	100,000	Jan 73
Penns Grove	.40	30,000	Oct 73
Penns Grove	.35	300,000	Aug 73
National Park	.12	60,000	Sep 73
National Park	.10	17,000	Dec 73
Penns Neck	.15	25,000	Jan 74
Penns Grove	.08	4,500,000	May 74
Pedricktown	.40	5,000	May 74
National Park	.10	15,000	Jun 74

CONCLUSIONS

41. Completed research under the DMRP has determined that reusable disposal facilities are feasible. The facts brought to light include the following:

a. A need exists for land disposal areas that are technically sound in design and are environmentally compatible for reuse over long periods of time.

b. Functions of a reusable disposal facility include dewatering and densification of solids, treatment of contaminated liquids and solids, resource storage and use, and disposal of unusable material.

c. Alternatives for maintaining and/or restoring the capacity of a reusable area include removal of material for landfill or other productive use, landfill or moundings on-site, or disposal of treated material in aquatic or inland disposal sites.

d. Information has been gained on the separation of the coarse fraction of dredged material; however, further research is necessary to develop techniques for mechanical dewatering of fine-grained dredged material.

e. There exists adequate authority for sale or donation of dredged material from reusable areas, and there are few legal constraints prohibiting the use of the material provided it is environmentally safe.

f. Benefits gained through reuse of disposal areas include retention of sites convenient to dredging operations, reduction in land-use and diking requirements, reclamation of valuable resources, and prevention of environmental degradation.

The results gained from further research in the areas of dredged material dewatering, treatment of contaminated dredged material, disposal area operations, and productive use will significantly contribute to evaluation of the reusable area concept. Research efforts will be combined with field studies and input from Corps Districts and Divisions in making area reuse a workable disposal alternative.

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DREDGING OPERATIONS IN THE GALVESTON DISTRICT

by

Colonel Don S. McCoy*

ABSTRACT

The author, who serves as District Engineer for the Galveston District, Corps of Engineers, U.S. Army, discusses dredging operations as related to the principal Federal channels constructed along the Texas Coast, commerce, dredging costs, and implications that environmental regulations and archeological problems are having on dredging. He also discusses some of the other benefits resulting from the Corps of Engineers dredging operations within his area of responsibility.

The Galveston District is responsible for the Federal navigation system in Texas, which totals approximately 1,000 miles of dredged shallow-draft and deep-draft channels ranging in depths from 6 to 45 feet.

These navigation channels serve a wide variety of users ranging from recreational to sports and commercial fishermen, and industry. He points out that major waterways users in Texas are the petroleum and petroleum-refining industries, which account for approximately 60 percent of all waterborne commerce in Texas. These industries pay over $700 million in wages, and ship goods valued at over $9 billion each year.

In July 1975, the Corps of Engineers new Federal Dredging Regulation (33 CFR 209.145) was published in the Federal Register. The intent of these regulations was to insure compliance with requirements of the National Environmental Policy Act of 1969 (NEPA) on all Federal projects. The new regulation significantly increases the time, cost, and the administrative

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work required to obtain the necessary coordination and concurrence of each disposal plan. He discussed the procedural tasks, preparation of environmental assessments, determination of findings, and other related matters.

The author discusses objections to disposal plans normally related to the discharge of dredged materials in open waters, unconfined land, and partially confined disposal areas. The impact of implementing dredging regulations, complying with NEPA, and adjusting to concerned environmental groups, have caused revisions of disposal procedures which have resulted in maintenance dredging costs. He reports that costs jumped 37 percent between Fiscal Year 1974 and Fiscal Year 1975, with escalation to 86 percent between Fiscal Year 1975 and Fiscal Year 1976.

The author concludes by reemphasizing that the Corps recognizes its responsibility to the public, the State and industry to maintain channels for all to use. Further, that it is a real challenge in the face of new regulations, spiraling costs, money constraints and environmental concerns.

INTRODUCTION

It is a pleasure to be with you to discuss dredging operations in the Galveston District. My remarks will include the principal Federal Channels constructed along the Texas coast, commerce, dredging costs, implications that environmental regulations and archeological problems are having on dredging, and, finally, some of the other benefits resulting from our dredging operations.

As a coastal district, Galveston is responsible for the Federal Navigation System in Texas which totals approximately 1,000 miles of dredged channels ranging in depths from 6 feet to 45 feet (Figure 1). This system is composed of 7 entrance channels supporting 15 deepwater ports, includes approximately 241 miles of deepdraft channels, and 704 miles of

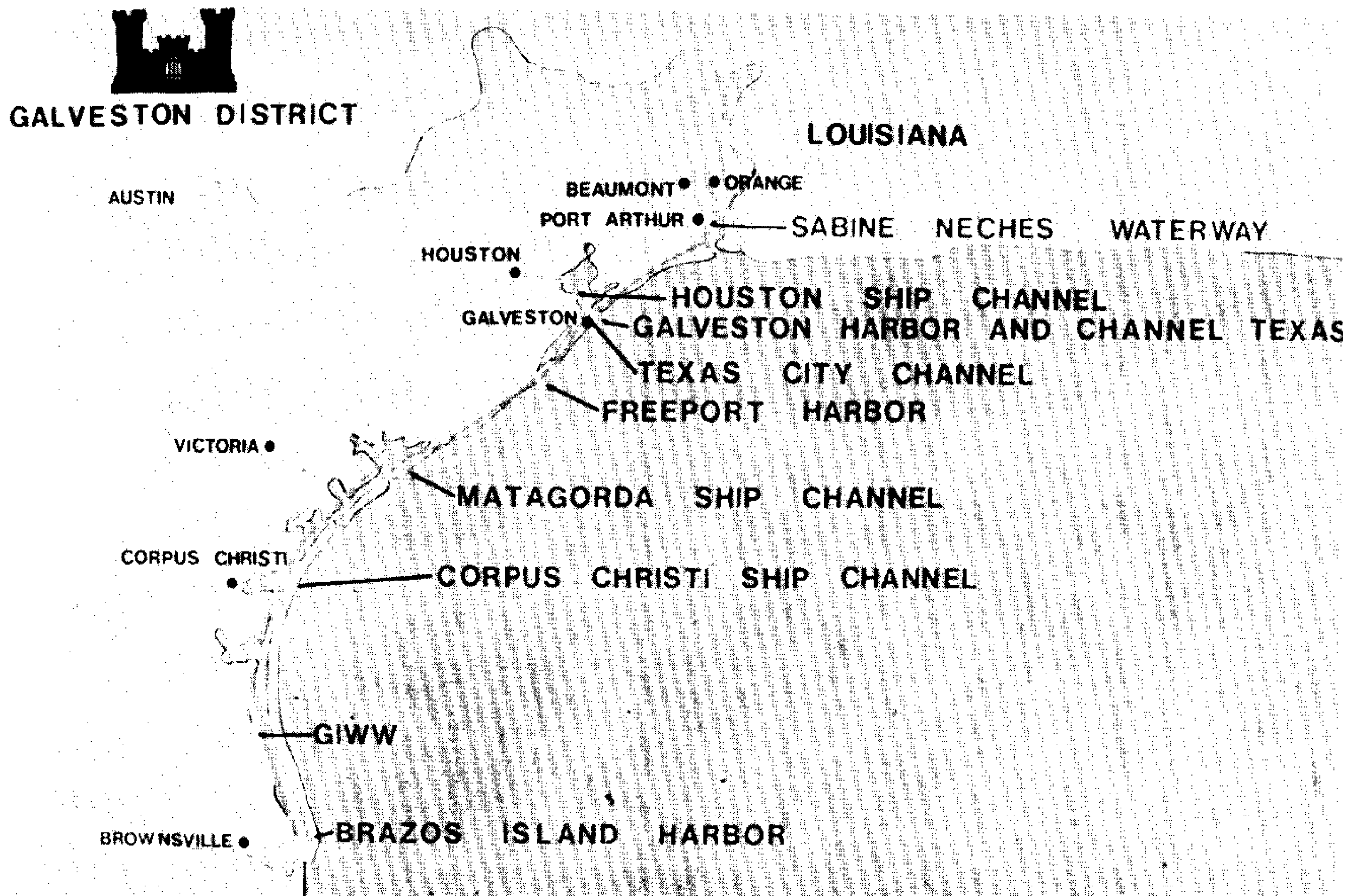

Figure 1. Principle Navigation Projects

shallow-draft channels. Of the shallow-draft channels, the 12-foot-deep Gulf Intracoastal Waterway (GIWW) is 404 miles long, traversing the entire Texas coast, and connects Brownsville with the Mississippi River and Florida (Table 1).

These navigation channels serve a wide variety of users, ranging from recreational to sports and commercial fishermen, (Figure 2) to industry (Figure 3). Water transportation is especially attractive to producers of low-cost bulk goods, as transportation costs may be a major factor in the cost of their products. Therefore, it is not surprising that the major waterway users in Texas are the petroleum and petroleum-refining industries. These two activities account for approximately 60 percent of all waterborne commerce in Texas. Other major users are the chemical and nonmetallic mineral industries, which account for 34 percent of all waterborne commerce in Texas. The importance of water transportation to these industries is further implied by the fact that they are heavily concentrated in the coastal counties. This is especially true in the case of petroleum-refining, where approximately 43 percent are located in coastal counties (Figure 4). In the coastal counties alone, these industries pay over 700 million dollars in wages, and ship goods valued at about $9.2 billion each year. Waterborne commerce handled by Texas ports set new records in 1974. Tonnages handled by Texas ports jumped more than 10 million tons for calendar year 1974, with record total of 241,089,200 compared to 230,690,009 for 1973 (Table II).

Tonnage transported on the Gulf Intracoastal Waterway between the Sabine River and Mexican border totaled 66,085,149 for 1974 compared to 63,002,285 the previous year.

The Port of Houston continued to lead the list of deepwater ports,

LESS THAN 25-FOOT DEPTH

CHANNEL	LENGTH, MILES	DEPTH, FEET
GIWW, MAIN CHANNEL	404	12
GIWW, TRIBUTARIES	189	6 TO 12
CHANNEL TO LIBERTY	44	6
MISCELLANEOUS CHANNELS	67	10 TO 12

OVER 25-FOOT DEPTH

CHANNEL	LENGTH, MILES	DEPTH, FEET
SABINE-NECHES WATERWAY	83	30 TO 40
GALVESTON HARBOR AND CHANNEL	16	40
HOUSTON SHIP CHANNEL	49	36 TO 40
TEXAS CITY CHANNEL	7	40
FREEPORT HARBOR	9	36
MATAGORDA SHIP CHANNEL	26	36
CORPUS CHRISTI SHIP CHANNEL	34	40 TO 45
BROWNSVILLE SHIP CHANNEL	17	36

Table 1. Principle Navigation Projects

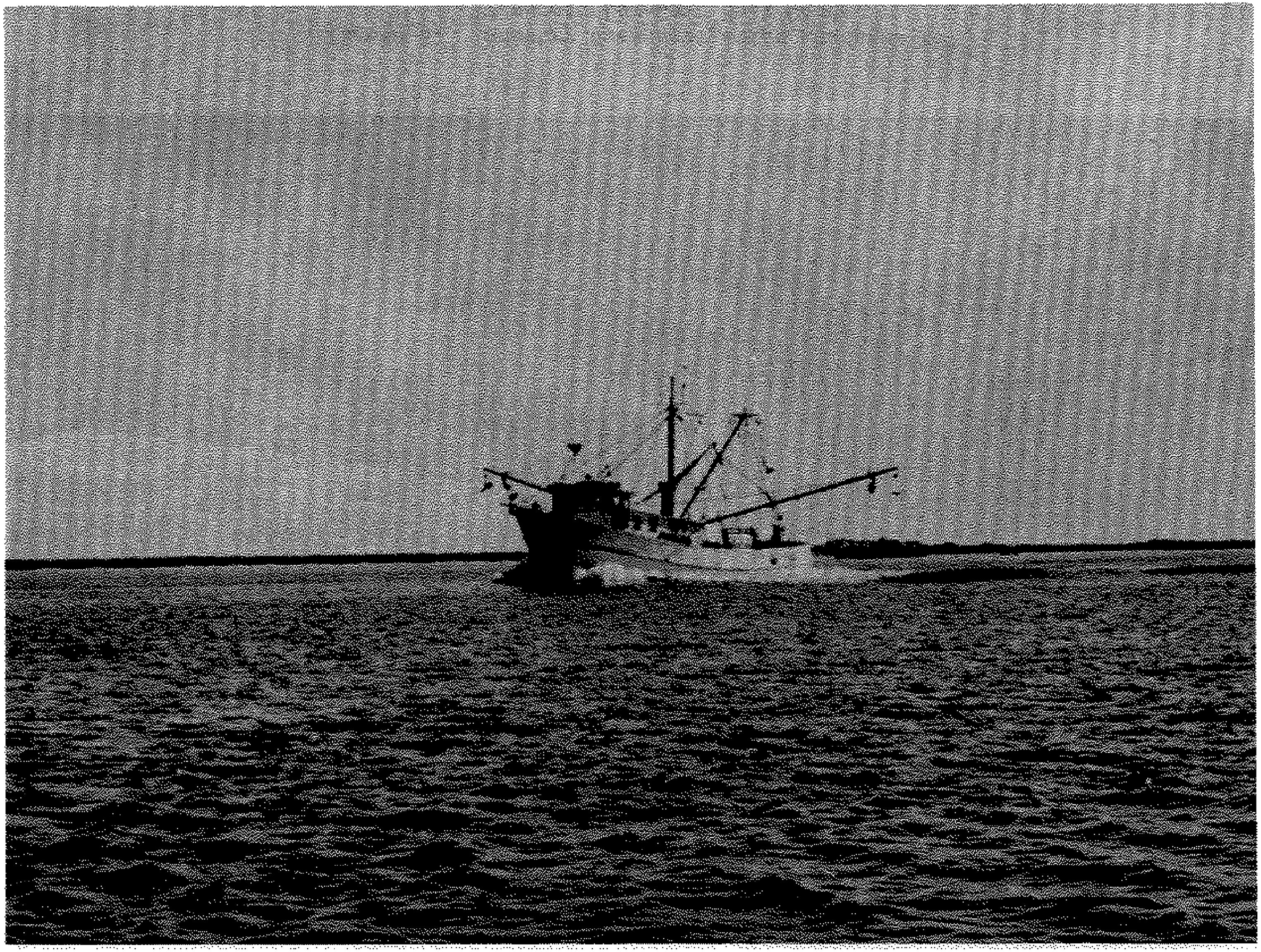

Figure 2. Navigation Channels are Vital to the Fishing Industry.

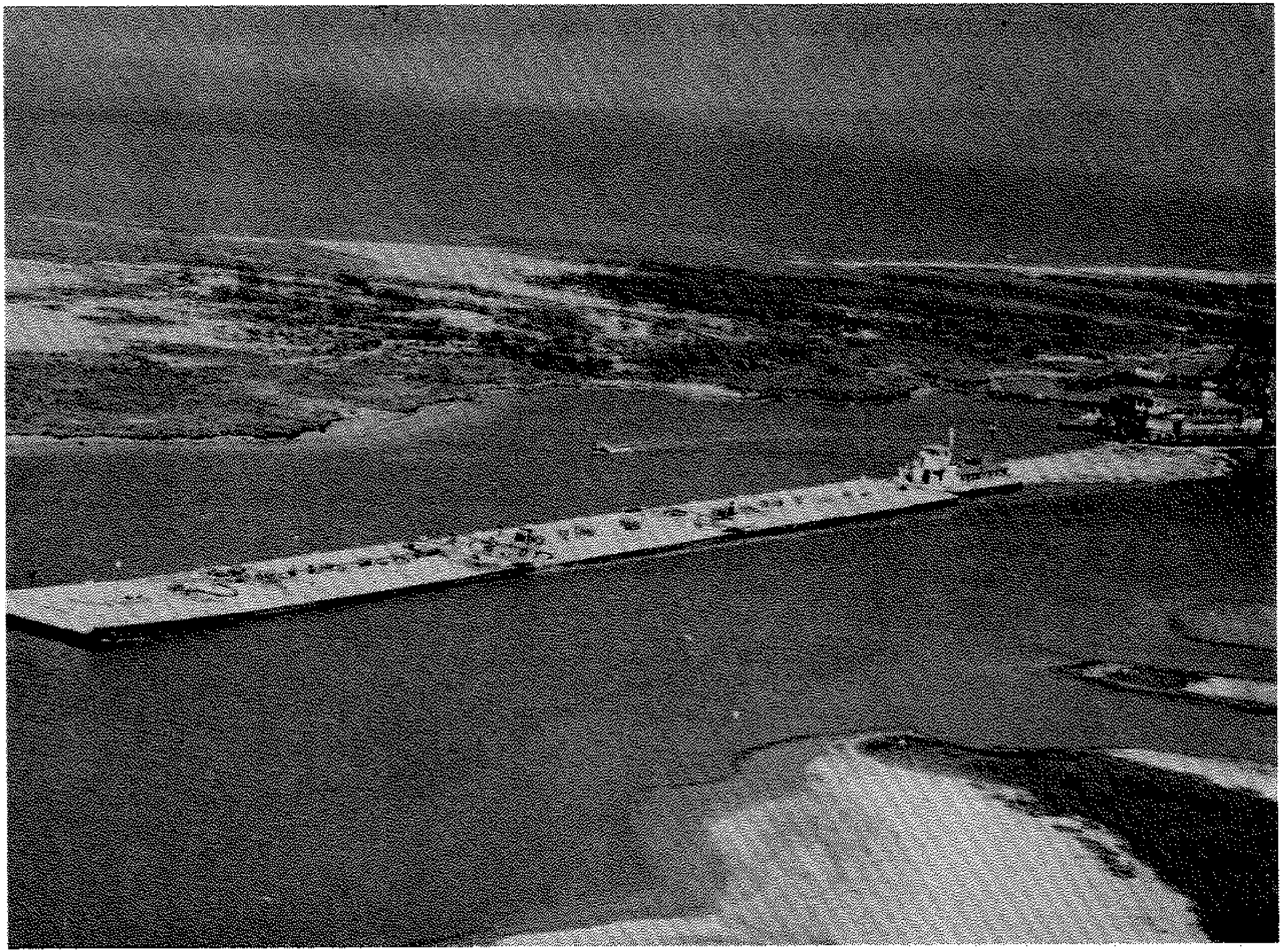

Figure 3. Industry Uses Navigation Channels To Transport Low-Cost Bulk Goods.

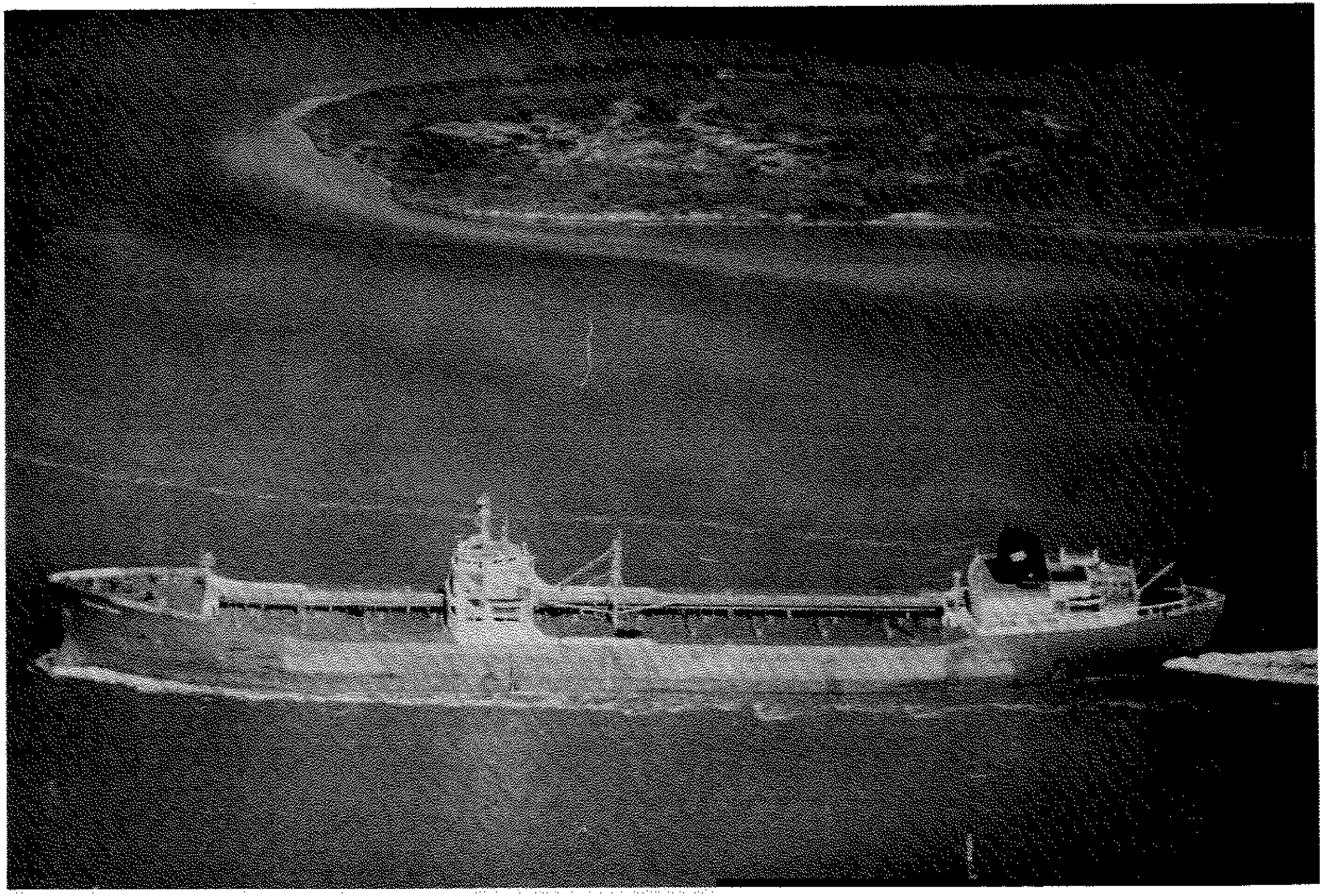

Figure 4. Petroleum and Petroleum Refining Industries Account for 60% of all Waterborne Commerce in Texas.

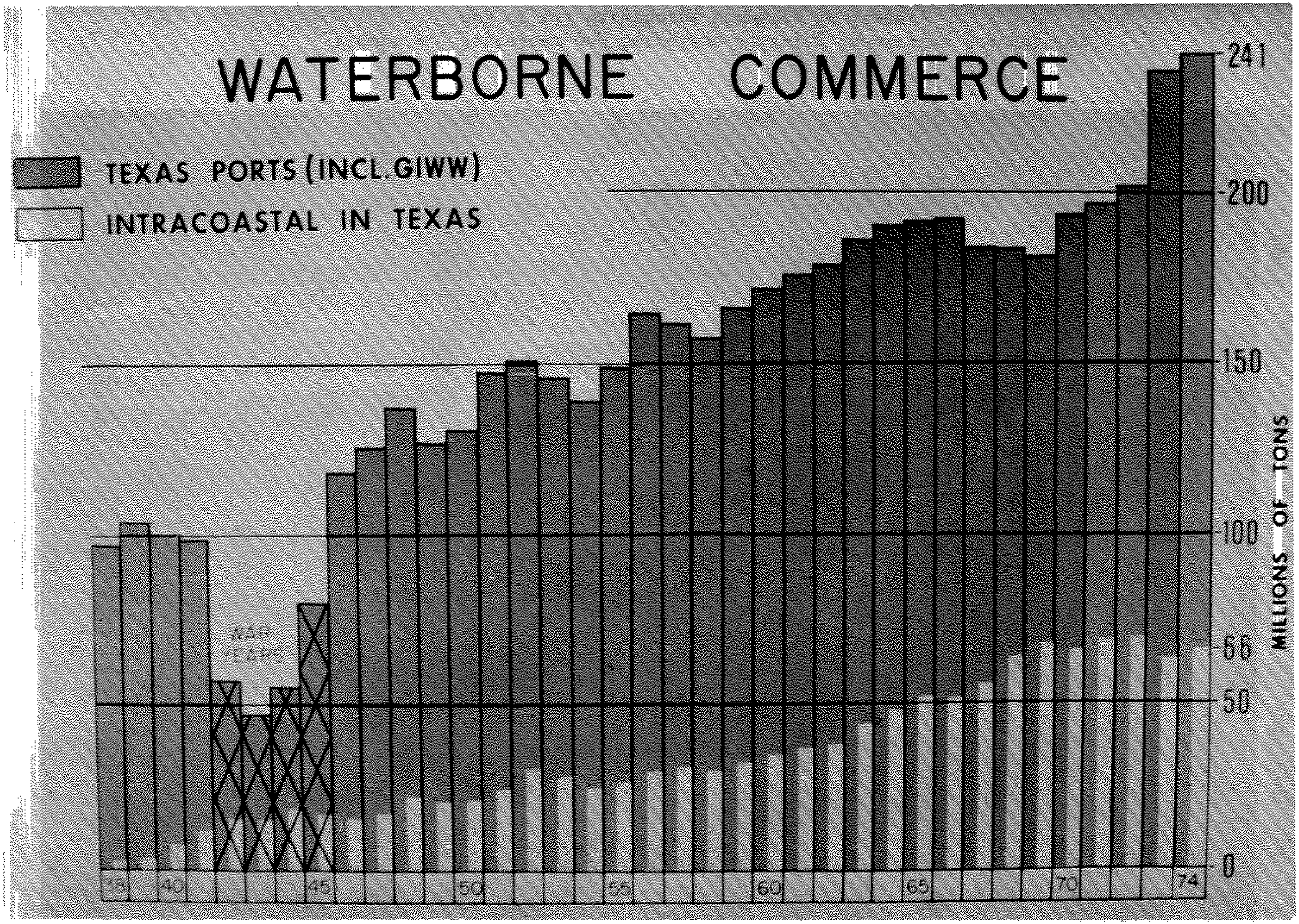

Table 2. Texas Waterborne Commerce.

with 89,106,389 tons for 1974--of which 58,782,402 were liquid cargoes. Corpus Christi moved into second place with 35,645,004, followed by Beaumont which recorded 33,503,880; Port Arthur with 27,799,593 and Texas City with 20,151,777.

In July 1974, the Corps of Engineers new Federal Dredging Regulation (33 CFR 209.145) was published in the Federal Register. The intent of the dredging regulations was to insure compliance with requirements of the National Environmental Policy Act of 1969 (NEPA) on all Federal projects.

The dredging regulation significantly increases the time, cost, and the administrative work required to obtain the necessary coordination and concurrence of each disposal plan. Last fall the immediate problem was to meet the stringent deadlines required by the regulation.

Procedural tasks for disposal plan approval include the issuance of the public notice, a 30-day response period, the resolution of any comments received, preparation of environmental assessments, determination and findings, statement of findings, submittal to EPA, response from EPA, and announcement of the decision by public notice. Since the issuance of the Federal Dredging Regulations, we have issued 32 of 34 public notices and have received EPA's approval on 26 disposal plans. We have prepared 20 of 21 draft environmental impact statements and have forwarded 12 of 23 final environmental statements to Council on Environmental Quality. We have had eight notices in the Federal Register.

Our experience to date indicates that the minimum time required from the date of public notice issuance to EPA approval of the disposal plans exceeds three months. This assumes there are no individual or organizational objections to the disposal plan.

On projects with objections, it may take considerably longer to complete the cycle. As an example, we issued the public notice for the Corpus Christi Ship Channel (Figure 5) on 19 September 1974, and after numerous meetings, a completed hurricane surge study by Texas A&M, and a Corpus Christi Bay water circulation study underway, we still have not resolved all the objections. Objections to disposal plans normally come from State or Federal fish and wildlife agencies. However, objections from private groups or individuals are not unusual. Nor is it unusual for comments received from groups whose interest lies in bird conservation to conflict with groups more interested in fish. Objections are normally related to the discharge of heavy metals into open water, discharge of dredged material into shallow bays, turbidity or disturbance of rookeries established on islands created from previous dredging. We have been able to resolve most of these objections by construction of confined disposal areas, pumping of greater distances to land areas, and seasonal dredging to avoid disturbance of rookeries during nesting season. We have also been able to cooperate with the environmental agencies during routine maintenance dredging, by dredging side channels to assist bay circulation and to provide fish passes, and by enlarging certain rookery islands (such as Brown Pelican Island) to accomodate expanding bird colonies (Figure 6).

There remain, however, several unresolved objections where we feel we have no alternative which will satisfy all interested parties.

The Galveston District is fortunate in that its work force includes more than its share of outdoor sportsmen, hunters, and fishermen. They have an inherent concern for conservation of fish and wildlife. Therefore, we have had no difficulty adjusting our thinking and procedures to provide optimum enhancement of fish and wildlife environments concurrent with economic and social benefits derived from transportation on the navigation

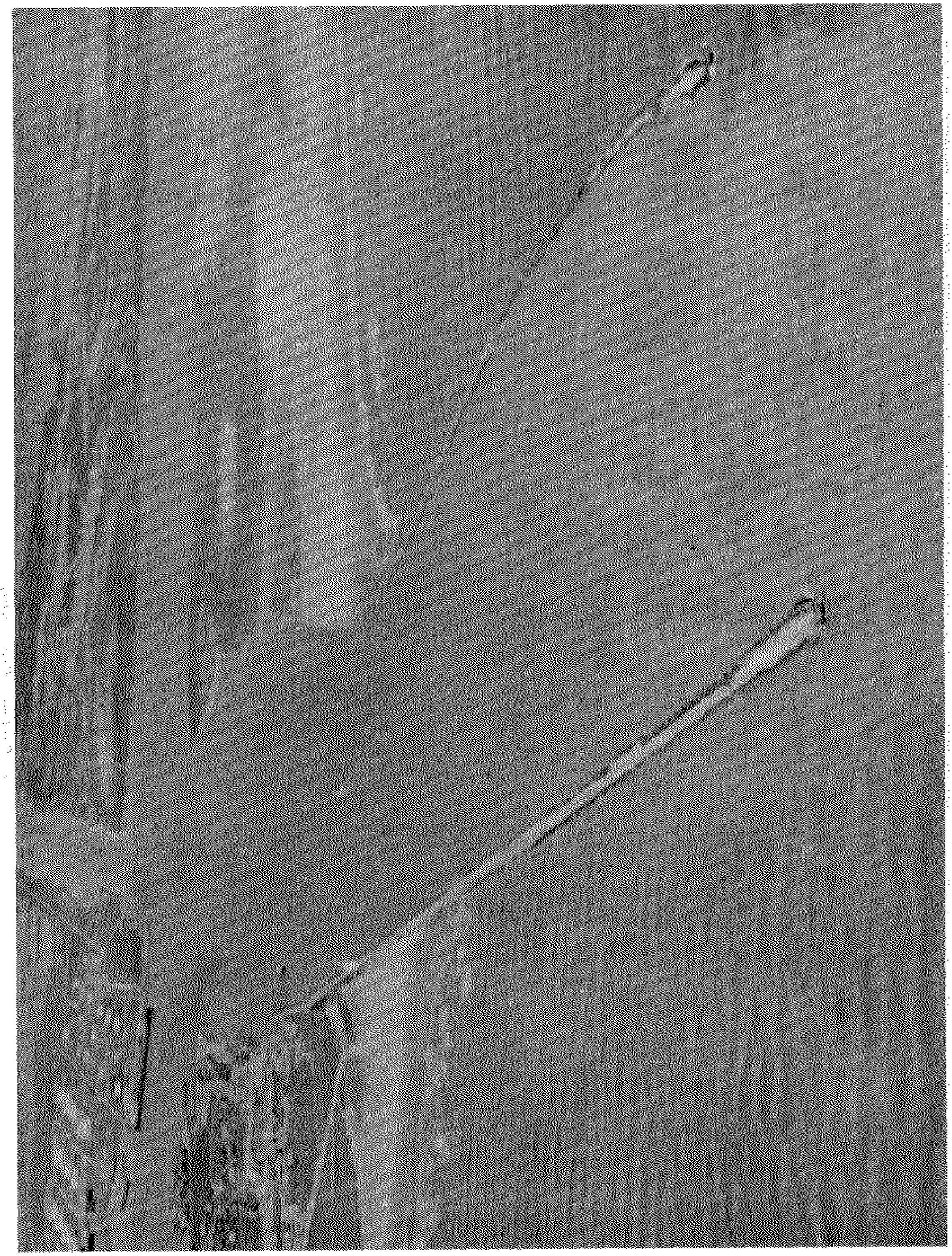

Figure 5. Corpus Christi Ship Channel.

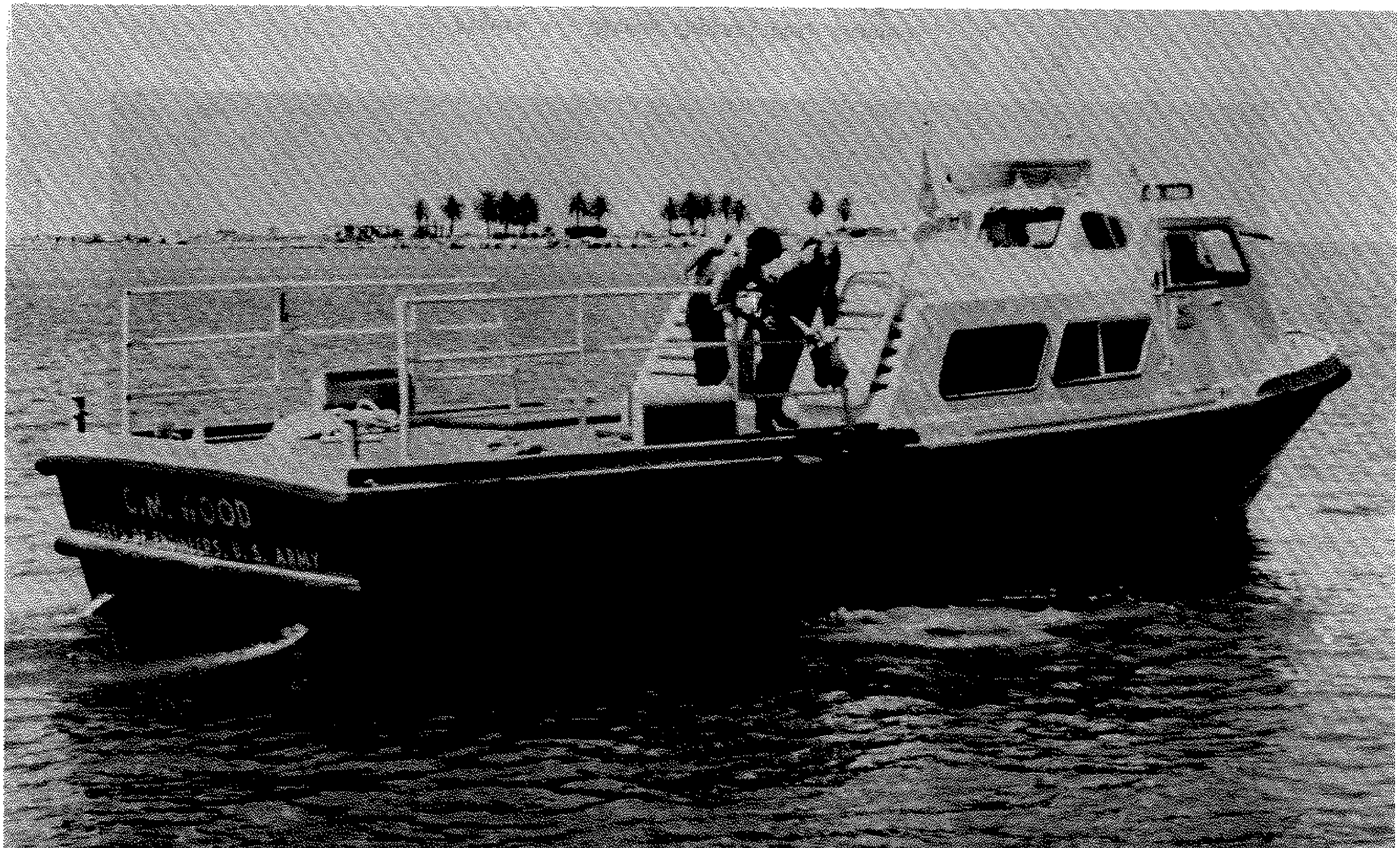

Figure 6. Maintenance of Environmental Quality is a Prime Concern.

channels. However, revision of disposal procedures, levee construction, increased pumping distances, studies and coordination procedures all increase the cost of maintenance program. The cost of dredging, including hopper dredging, has increased significantly over the past several years, with the Fiscal Year 1975 unit costs exceeding Fiscal Year 1974 by over 37 percent. These increases are attributed to three major sources: (1) Inflation, (2) Compliance with the National Environmental Policy Act and other statutes, and (3) Changed procedures for disposal of dredged material. Inflation we are all familiar with. In the dredging business it manifests itself as increased labor costs, both direct and indirect, and as significant increases in fuel, parts, and pipeline costs. All of these inflationary trends are reflected by increased contract costs per cubic yard of shoal material removed.

Costs related to NEPA and other statutes are also significant and are not onetime events. Data collection, analysis, coordination and processing of EIS's on maintenance dredging for the 1,000 miles of navigation channels in Galveston District have been a high priority effort (Figure 7). The public notice process and resolution of objections have highlighted areas of citizen concern. Water sample collection, laboratory testing, and analysis required by EPA is becoming a costly routine.

Trends concerning archeological investigations are also increasing. Figure 8 shows the locations of projects where we have encountered archeological problems. These include numerous shell midden sites, shipwrecks which occurred in the year 1554, and preservation of a military depot used in 1846 by General Zachary Taylor during the Mexican War. Recently, shell middens located in a disposal area along the Houston Ship Channel delayed the removal of shoals along a 3.3 mile section of the channel until an archeological site survey could be completed by the Texas Historical

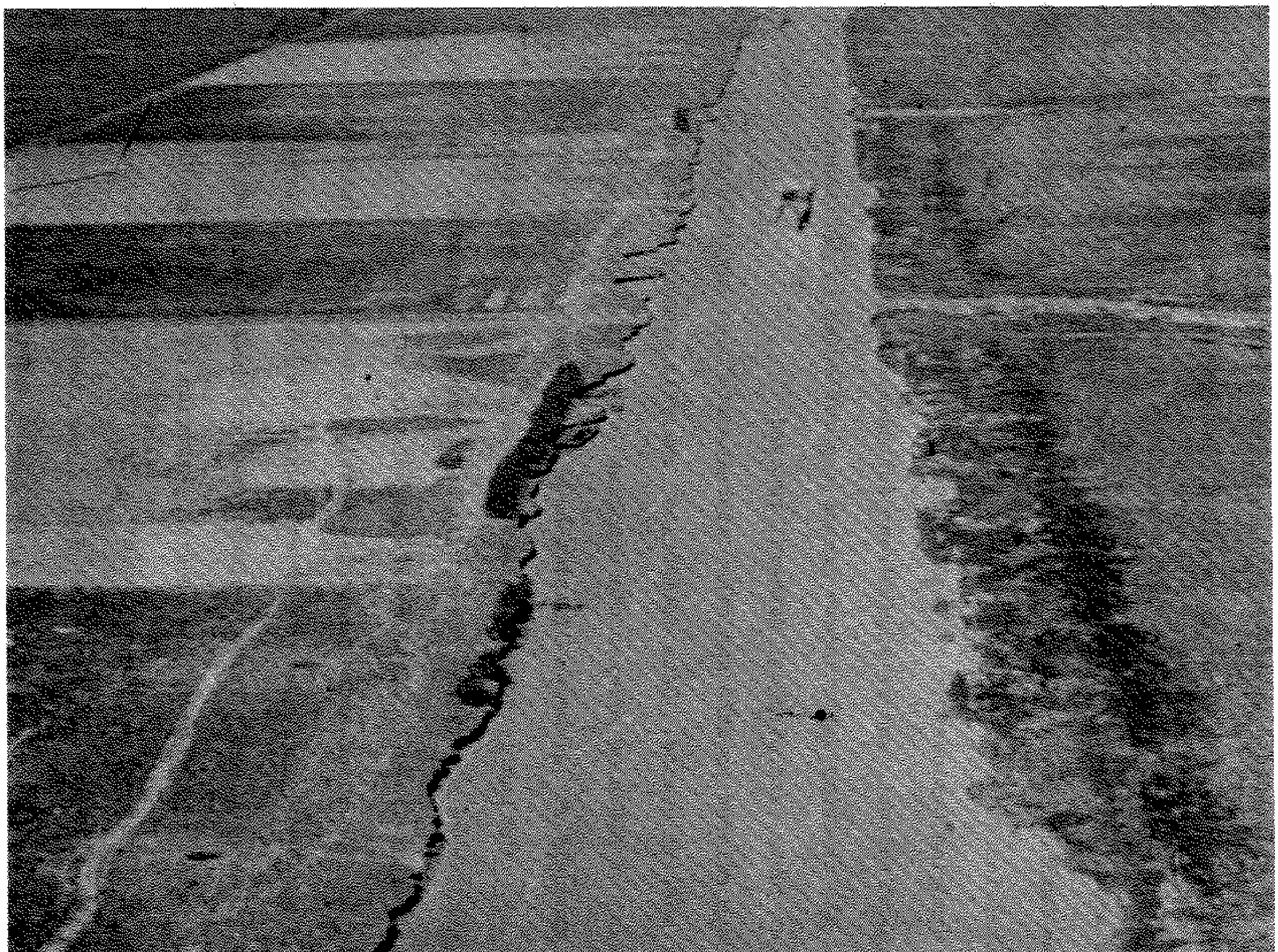

Figure 7. Maintenance Dredging of 1,000 Miles of Navigation Channels in Galveston District has been High Priority Effort.

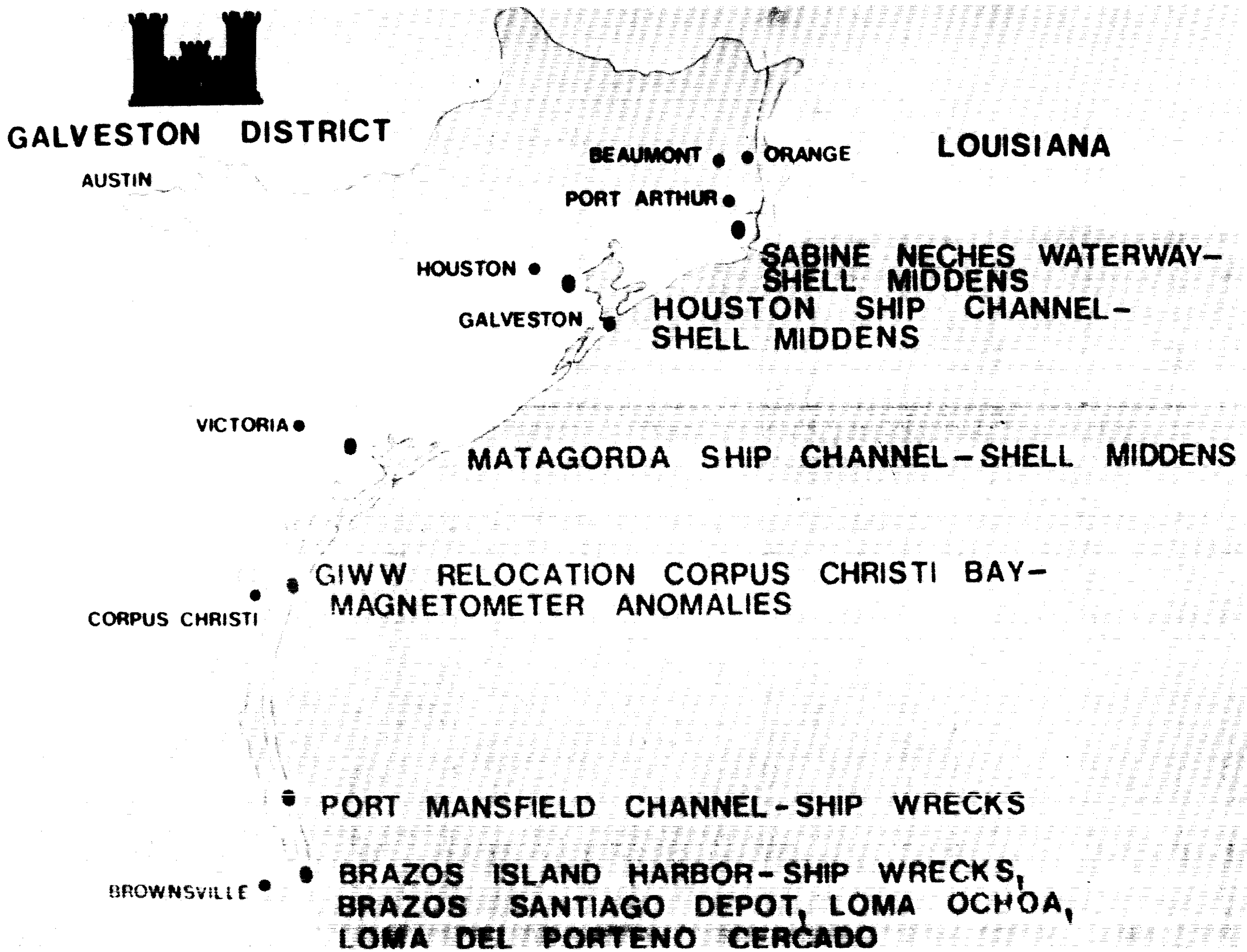

Figure 8. Principle Archeological Sites.

Commission. Incidentally, these sites are not in new disposal areas, but are in areas where we have been dredging and disposing of dredged materials for many years.

I estimate that increased costs related to statutory effects in the Galveston District were about $800,000 in Fiscal Year 1975.

Fish and Wildlife coordination has resulted in reduction of open water disposal areas and increased use of dry land disposal. A desire to reduce turbidity and improve water quality has increased the size and depths of leveed disposal areas. Control structures are also required to optimize decanting time. Abandonment of open water or wetland disposal areas has increased pumping distances. All of these factors result in higher cost per cubic yard of maintenance dredging. In times of budget constraints, fund shortages combined with increased unit costs result in deferral of previously programed maintenance dredging.

Table III illustrates the amount of money we spent during Fiscal Year 1975 and plan to spend in Fiscal Year 1976 on all O&M dredging. Note the difference in quantity dredged for about the same price between this year and last year. During Fiscal Year 1975 Galveston District initiated and/or completed 23 maintenance dredging contracts, removing 37 million cubic yards of shoal material at a cost of $18.8 million, including hopper dredging. In Fiscal Year 1976, we are initiating and/or completing only 12 contracts, including hopper dredging. We will remove about 21 million cubic yards of shoal material at a cost of $19.5 million.

Table IV shows our cost per cubic yard of maintenance-dredged material for Fiscal Year 1974, Fiscal Year 1975, and Fiscal Year 1976. Note our costs jumped 37 percent between Fiscal Year 1974 and Fiscal Year 1975, and 86 percent between Fiscal Year 1975 and Fiscal Year 1976. Several projects

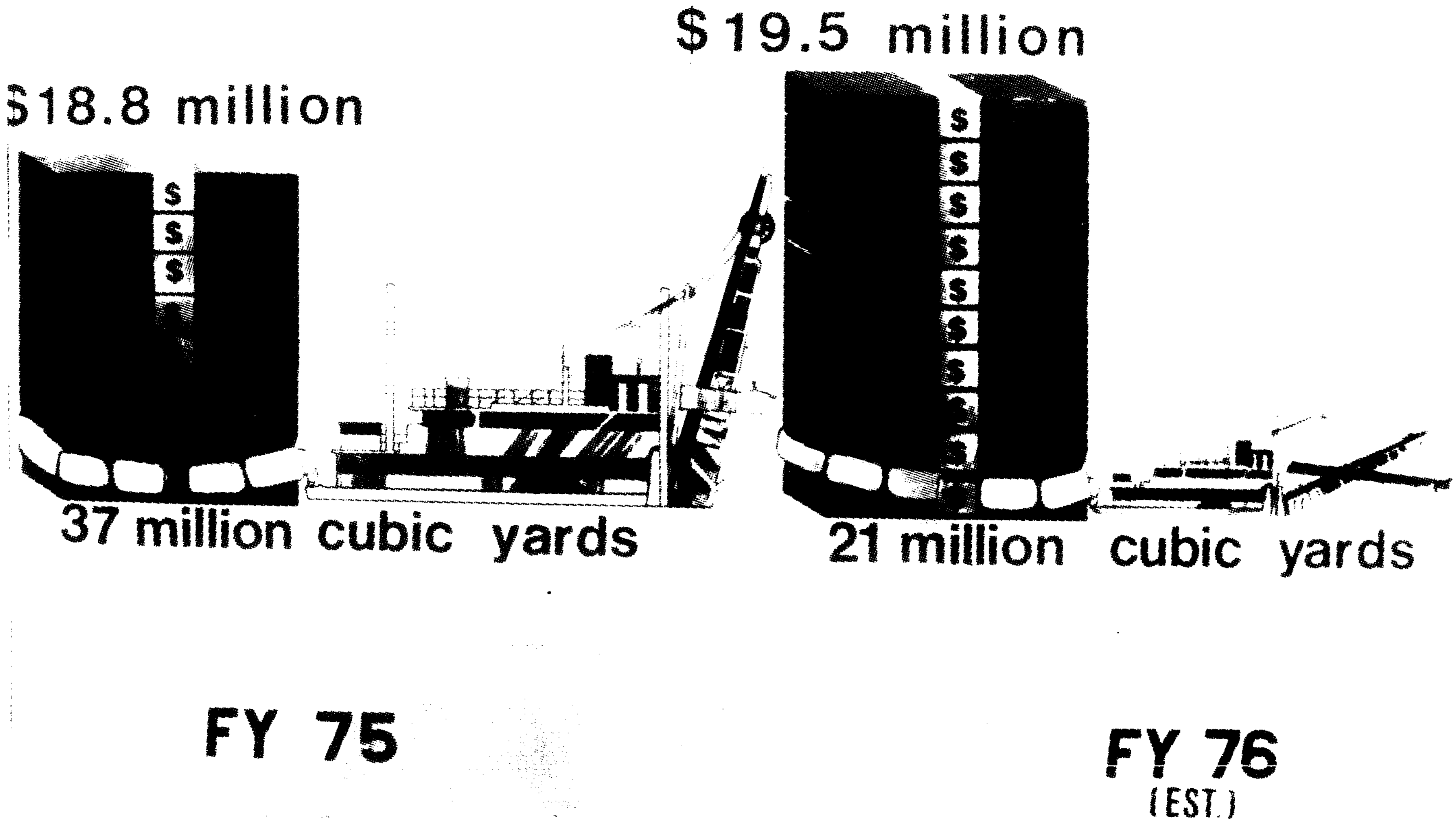

Table 3. Fiscal Comparison of Maintenance Dredging in Galveston District 1975-1976.

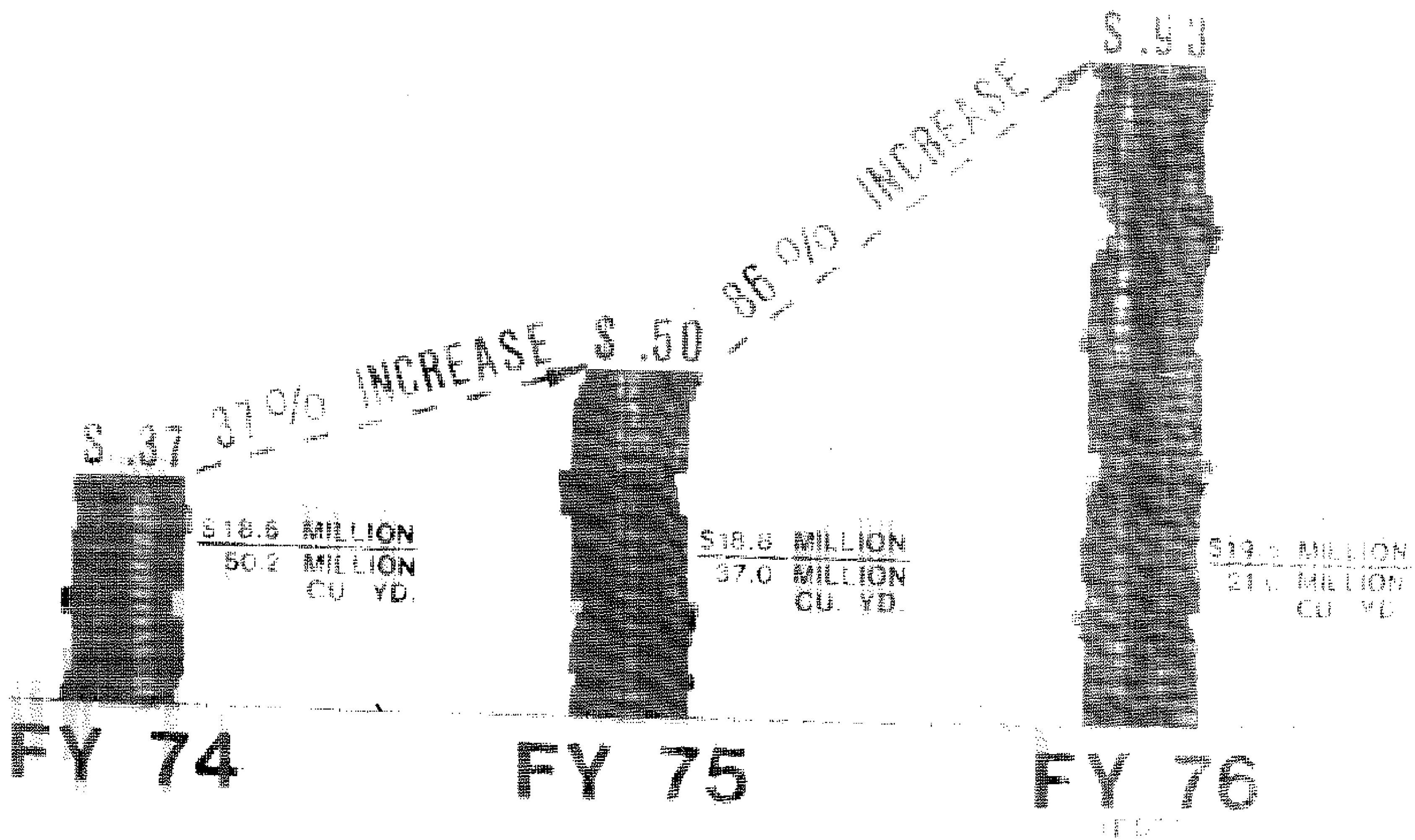

Table 4. Cost Comparison per Cubic Yard of Maintenance-Dredged Material for Fiscal Year 1974, Fiscal Year 1975, and Fiscal Year 1976.

are in critical need of dredging. However, we have no funds available to initiate additional contracts and this backlog estimated at $22,075,000 by the end of the Fiscal Year 1976 transition quarter, will be carried into the next fiscal year.

We utilize four different types of disposal areas in our dredging operations. These are confined or leveed (Figure 9), partially confined (Figure 10), unconfined (Figure 11), and open water (Figure 12). Generally, we only use open water areas where water depths are too deep to construct levees or where pumping distances are too great to be economically feasible. Open water and unconfined areas are usually the ones most criticized by conservation and environmental groups. We have found, contrary to objections received, that often these areas provide shallow waters which are valuable nurseries for fish and marine life. Emergent areas develop into important rookeries. Sydney Island is a good example (Figure 13). Sydney Island supports a large nesting colony of shore birds and wading birds. Surveys by the Research Department of the National Audubon Society indicate that Sydney Island has the largest total aggregate number of breeding egrets, herons, ibises, spoonbills, cormorants, gulls, and terns on the Texas coast. An aerial survey of Sydney Island conducted in May 1972, revealed 11,400 pairs of birds of 12 species. Included were 1,200 pairs of roseate spoonbills (Figure 14), a threatened species.

Another example of an emergent disposal island is Brown Pelican Island adjacent to Corpus Christi Ship Channel (Figure 15). The brown pelican, an endangered species, nests on this island.

CONCLUSION

No one is more concerned than the Corps of Engineers regarding the effect dredging has on the environment. We recognize that practices used years ago

Figure 9. Leveled Dredge Material Disposal Site.

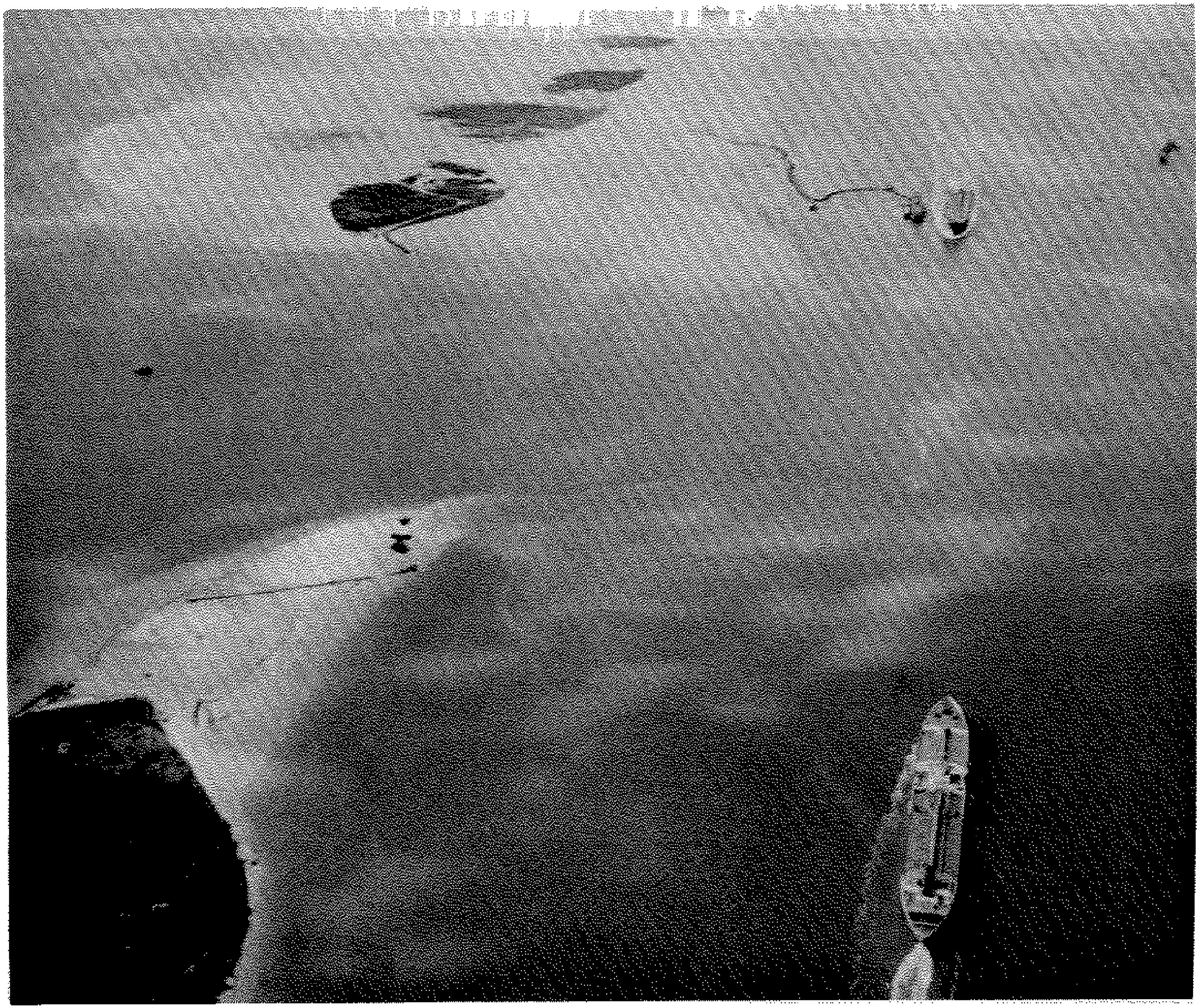

Figure 10. Partially Confined Dredge Material Disposal Sites.

Figure 11. Unconfined Dredge Material Disposal Site.

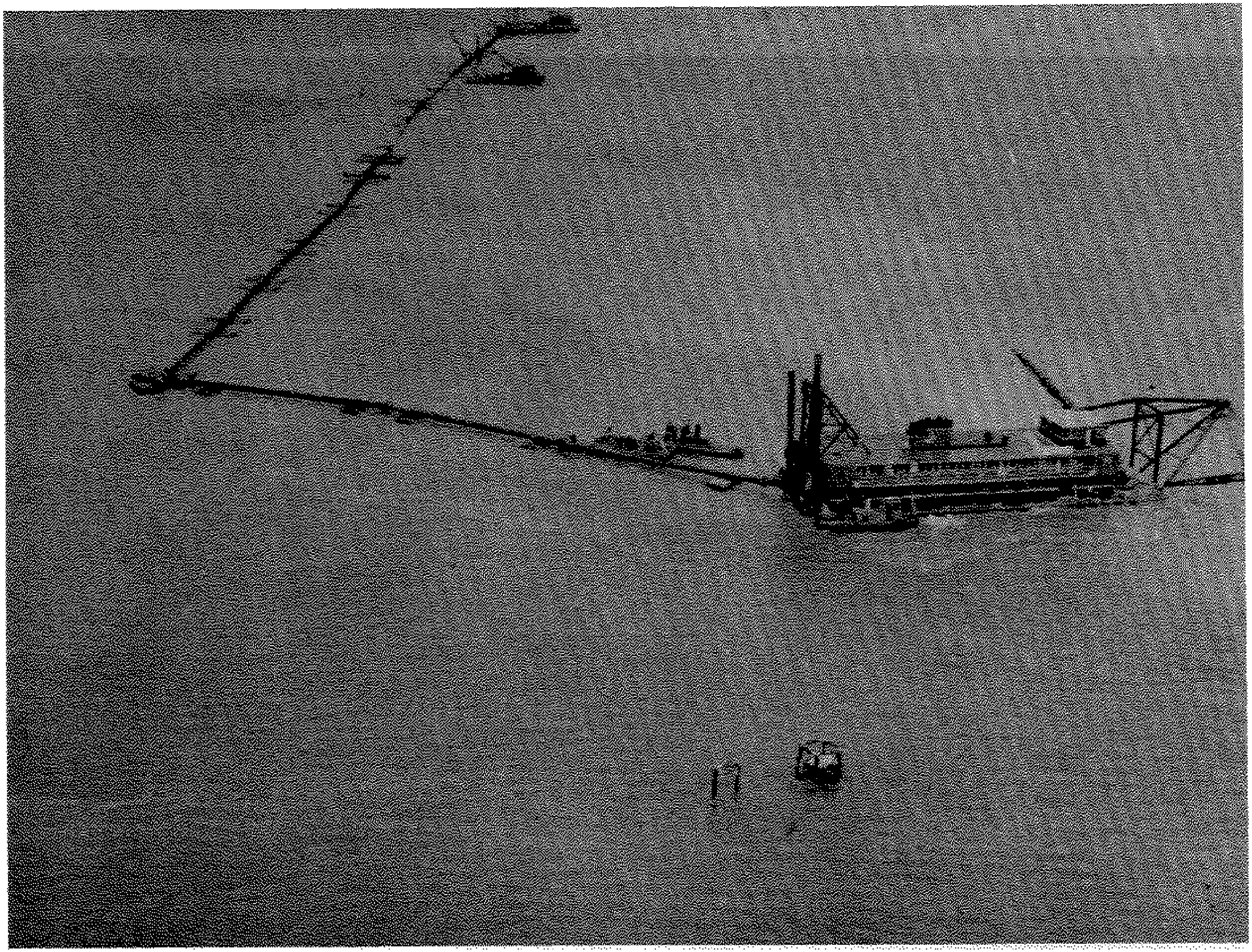

Figure 12. Open Water Dredge Material Disposal Site.

Figure 13. Sidney Island.

Figure 14. Roseate Spoon Bill.

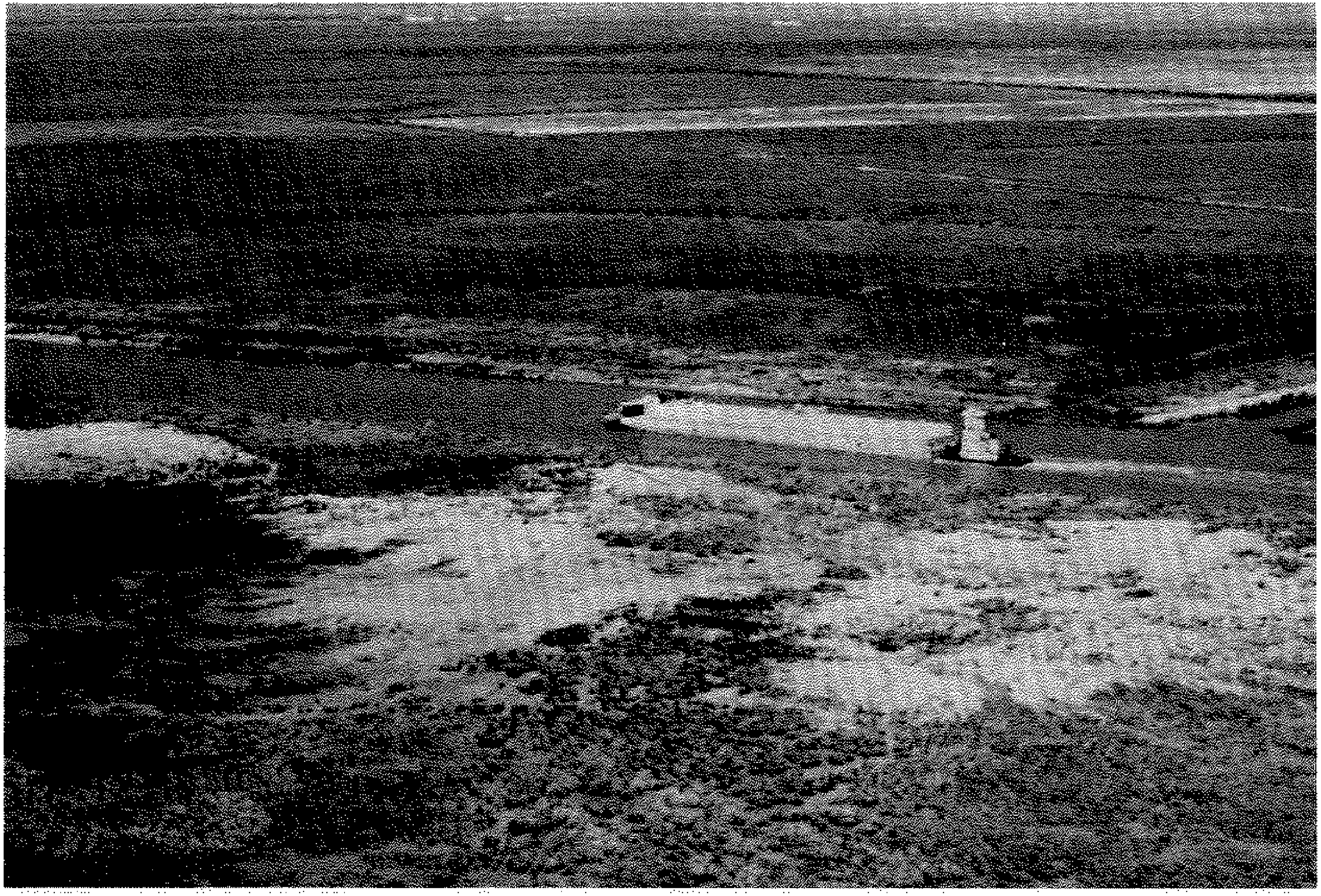

Figure 15. Corpus Christi Ship Channel.

need updating and, in fact, we are doing just that. We also recognize our responsibility to the public, the State, and industry to maintain channels for all to use. These days, it is a real challenge to do this in face of new regulations, spiraling costs, money constraints, and environmental concerns. This concludes my comments on dredging operations in the Galveston District. I will be happy to answer any questions you may have.

DREDGE MATERIAL CONTAINMENT IN NYLON BAGS IN THE CONSTRUCTION OF MINI-PROJECTS FOR BEACH STABILIZATION

by

Jerry L. Machemehl, Ph.D., P.E.*

ABSTRACT

Erosion in the vicinity of Lockwoods Folly Inlet, N.C. has been serious. Between 1943 and 1972 a high rate of shoreline erosion existed along the easternmost 6,000 ft (1829 m) of Holden Beach. Erosion occurred at an inordinate and rather steady rate of 14.7 ft/yr (4.5 m/yr). Valuable oceanfront lots were lost, beach cottages were damaged and sections of North Carolina Highway 132 were destroyed as a result of the erosion.

To provide an interim solution to the problem the Office of Water and Air Resources, North Carolina Department of Natural and Economic Resources, received $50,000 from the Governor's Emergency Funds for an experimental erosion control project for the east end of Holden Beach.

INTRODUCTION

The Barrier Islands of North Carolina, an important natural asset to the State, are perennially plagued with wind and water erosion. Because of the economic and recreational value of the beaches, it was imperative that low-cost, innovative structures be developed and utilized to combat the erosive forces of wind and water. Since 1960, North Carolina Barrier Islands have developed into popular summer resort communities. These coastal developments have created a multitude of engineering problems.

In general, the dynamic nature of the Barrier Islands has been

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disregarded by land developers in North Carolina. Only when severe damage or acute erosion is imminent have the developers been interested in remedial actions often pursued late or cursorily.

DESCRIPTION OF THE PROJECT AREA

Holden Beach is located in Brunswick County, N.C. between Lockwoods Folly Inlet to the East and Shallottee Inlet to the west. The alignment of the shoreline in the vicinity of Lockwoods Folly Inlet is almost east-west in direction (see Figure 1). The beach is approximately 44,000 ft (13,400 m) long and has an average width of 1600 ft (490 m). The eastern end of the beach has been a victim of considerable erosion. The Corps of Engineers (7) has stated that the eastern 6,000 ft (1,800 m) of Holden Beach has experienced the highest rate of shoreline erosion in Brunswick County (see Figure 2).

FIELD SURVEY OBSERVATIONS

In 1967, Stafford (2) conducted field survey observations in Brunswick County, N.C. on the east end of Holden Beach. He observed severe erosion and reported:

> "At the surfside pavillion, near the east end of the island, a vertical wooden seawall is necessary to protect the structure behind it. The seawall is approximately 40 ft seaward of the existing dune line and during the course of this investigation additional erosion around the seawall was observed. The area further east is experiencing continued erosion and many of the residential structures have seawalls for their protection.
>
> Lockwoods Folly Inlet, at the eastern end of the island, shows definite signs of westerly migration. The roadway is being actively eroded as well as the dunes which exhibit a rather high, steep scarp. The easternmost houses along the beach require the protection of a seawall. An additional seawall and groin system was constructed during the spring of 1967. While the August 1967 survey indicated some accretion around the groins, evidence of continued erosion of the general

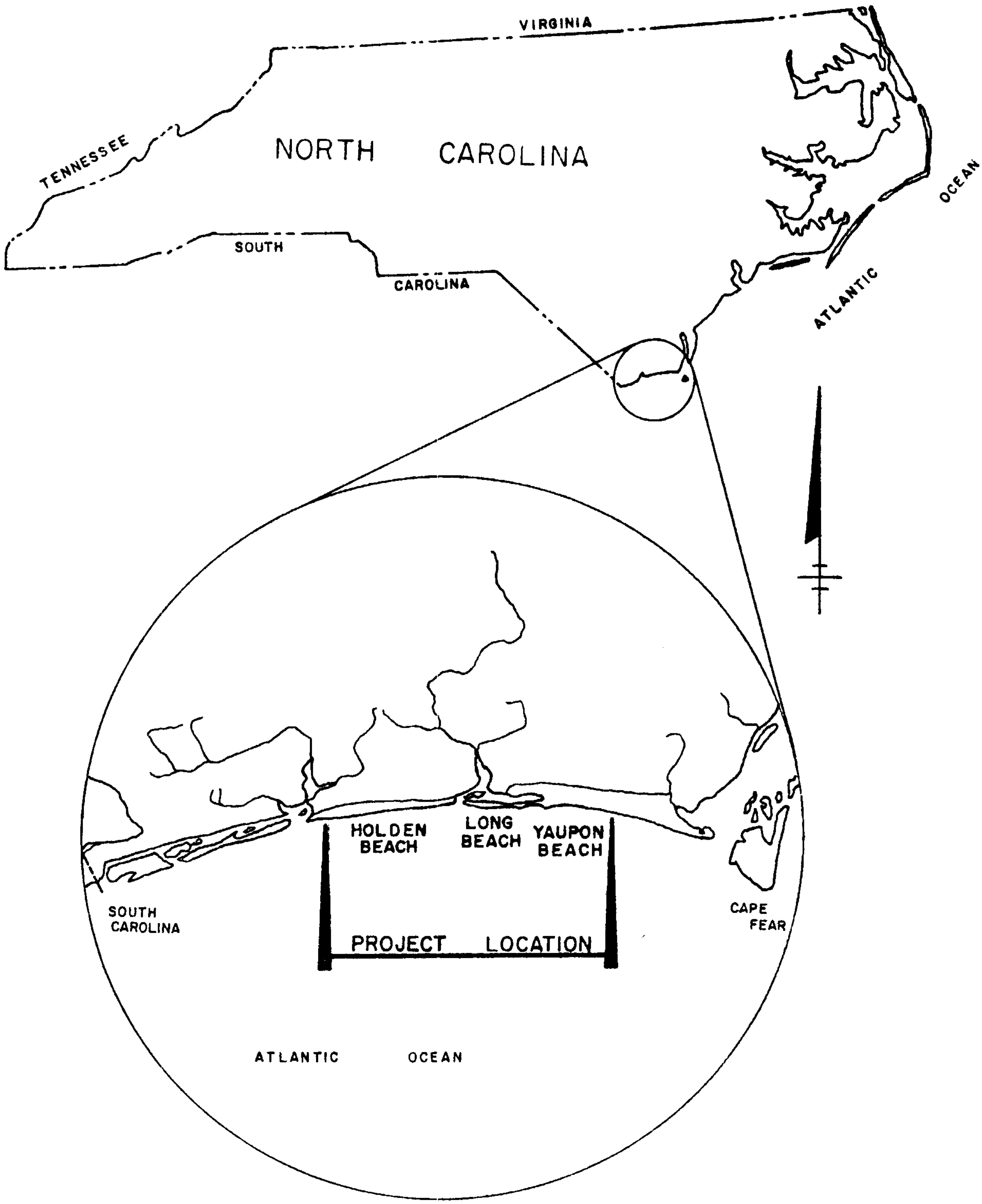
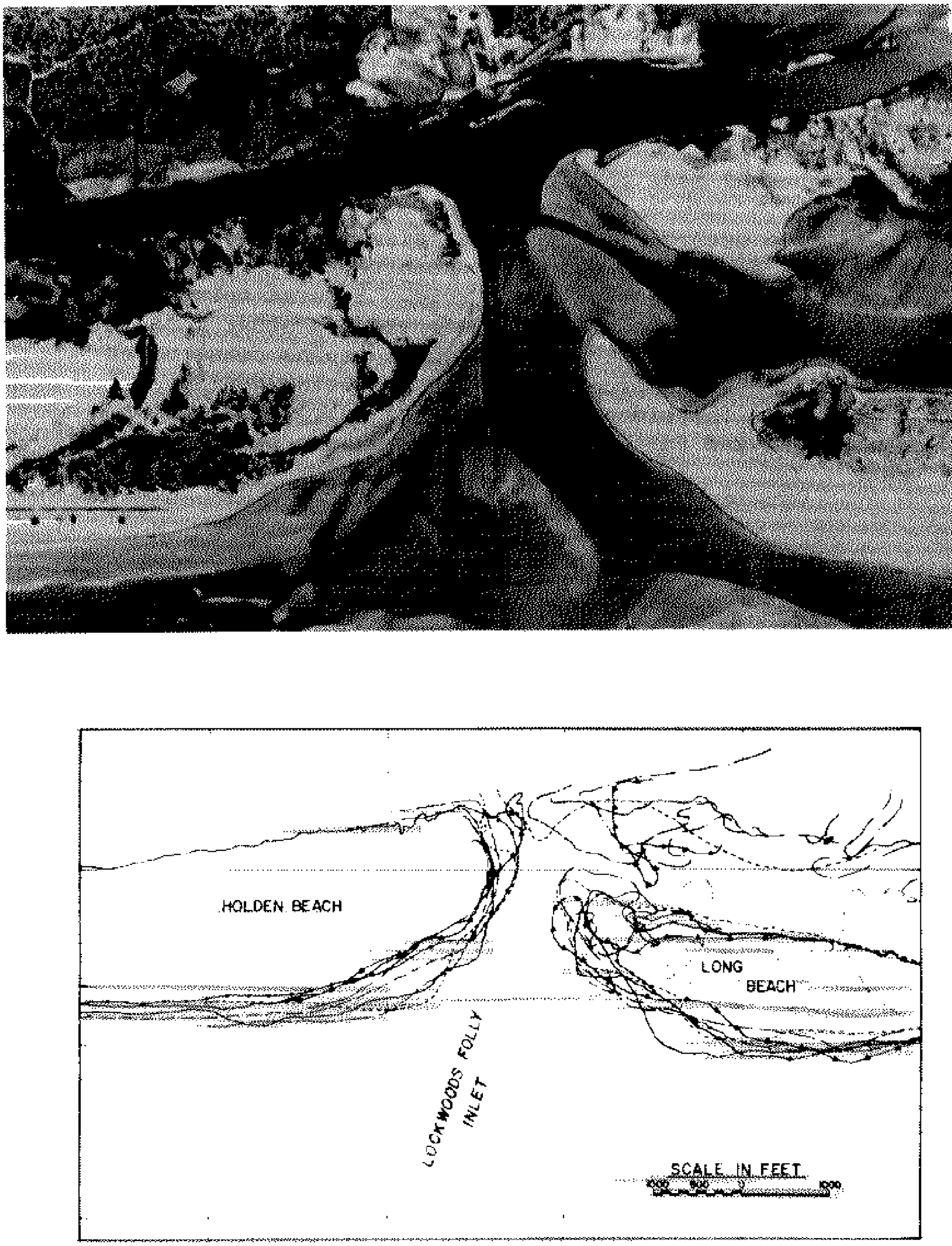


FIGURE 1. PROJECT LOCATION



LEGEND

DATE	HIGH WATER SHORELINE
1859	
1923	
1934	
1943	
1954	
1961	
1963	
1970	
1972	

FIGURE 2.
LOCKWOOD FOLLY INLET,
BRUNSWICK COUNTY, NORTH CAROLINA

area was also noted. Several truckloads of fill placed just east of the new seawall were subsequently removed by erosion".

FIELD OBSERVATION (1970)

In 1970, Machemehl made the following observations:

"Severe erosion occurring on the west side of Lockwoods Folly Inlet is destroying valuable oceanfront lots along with several hundred feet of State road. Several cottages have been moved from the area and relocated on other lots on the beach. Timber bulkheads and small groins constructed by local residents and property owners are being destroyed (See Figure 3). The timber bulkheads are poorly designed and constructed and for the most part have been neglected for years".

METEOROLOGICAL AND OCEANOGRAPHICAL DATA

A wind rose indicated that the winds blow offshore (from the northwest, north and northeast) 35.1 percent of the time, onshore (from the southwest, south and southeast) 35.4 percent of the time and alongshore (from the east and west) or calm 29.5 percent of the time (See Figure 4). The predominant winds (duration and speed) occurred from the southwest quadrant. The data were found to be generally well correlated with the direction of waveheight data.

Waveheight and direction data were available from several sources. The data gathered from ships sailing in the 1° geodetic grid square 33-34° N, 77-78° W were used in the analysis of the project area. Evaluation of the ship data showed a predominant south to southwest wave direction. The waves had a period less than 9 sec and a height less than 5 ft (1.5 m).

The mean tidal range at the beach is 4.2 ft (1.3 m). The spring tidal range is 4.8 ft (1.5 m).

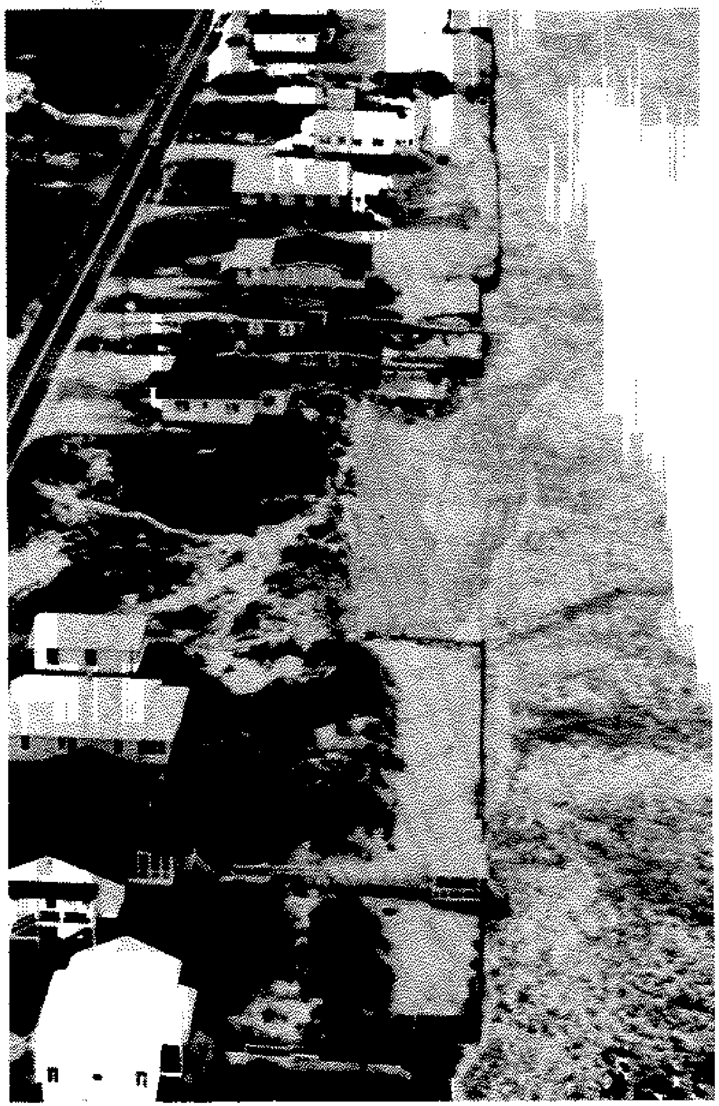


FIGURE 3. LOOKING EAST AT HOLDEN BEACH
BRUNSWICK COUNTY, NORTH CAROLINA

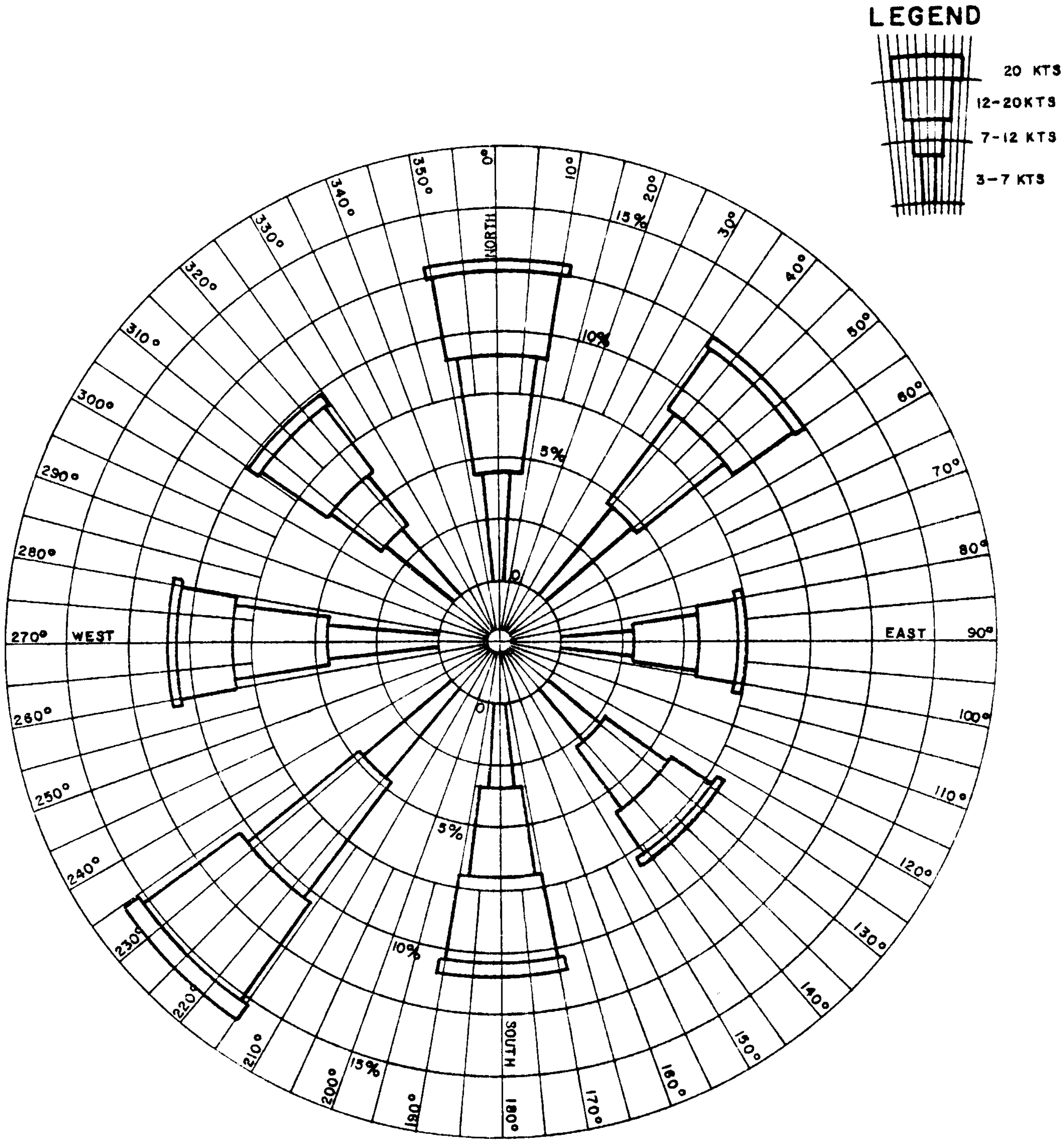


FIGURE 4

WIND SPEED VS. DIRECTION FOR WILMINGTON, N.C. (1948-1960).

COASTAL PROCESSES

WAVE REFRACTION ANALYSIS

A wave refraction analysis (prepared by the U.S. Army Coastal Engineering Research Center (7) was used during the study of the project area. Wave refraction diagrams for 8 sec period waves from east 60° south, south 30° west and south 60° west are shown in Figures 5 through 8. The wave refraction analysis revealed that the east end of Holden Beach is an area of high wave energy concentration.

LONGSHORE TRANSPORT

Longshore transport curves (prepared by the U.S. Army Coastal Engineering Research Center (7) were used to analyze the sand movement and erosion potential at Holden Beach. The longshore transport from the west was approximately 460,000 yd^3/yr (351,695 m^3/yr) while the longshore transport from the east was approximately 140,000 yd^3/yr (107,038 m^3/yr). A comparison of total longshore transport showed the predominant direction of sand movement was from the west to the east with the easterly component ranging from 2.5 to 3.5 times the westerly component. Due to the southeasterly alignment of the inlet channel as shown in Figure 2, the westerly transport was intercepted by the inlet bar. Approximately 240,000 yd^3/yr (183,493 m^3/yr) accumulated on the offshore bar and in the intracoastal waterway (See Figure 9).

EROSION

The erosion of the east end of the beach has been extensive. The cumulative shoreline changes are shown in Figures 10 and 11.

EROSION CONTROL STRUCTURES

The groin is the most universally used erosion control structure.

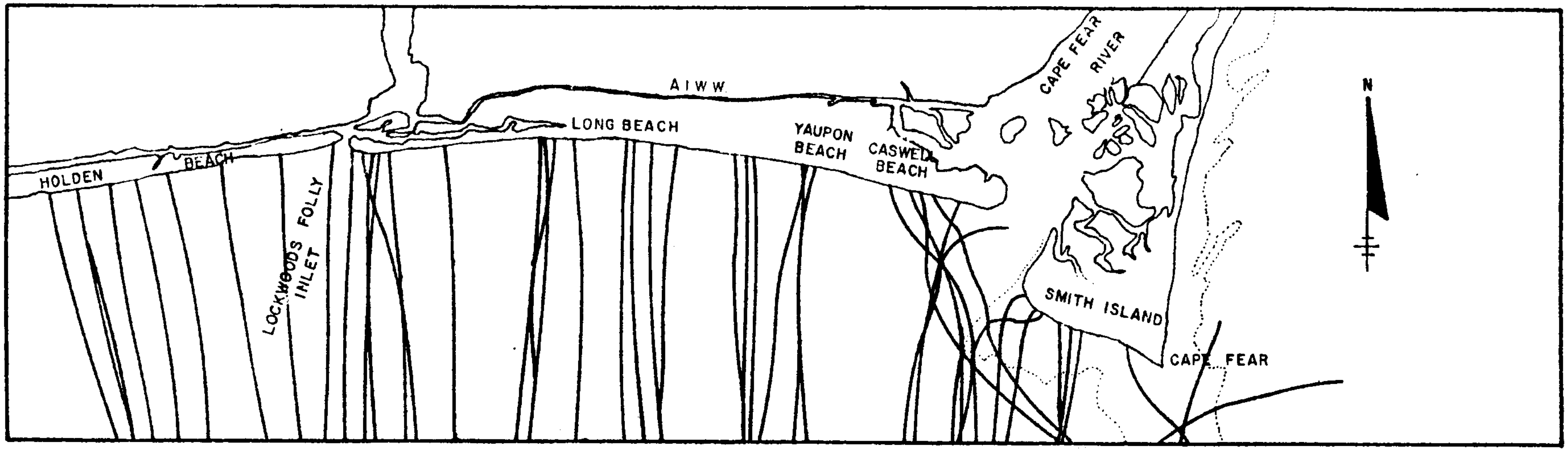


FIGURE 6

WAVE REFRACTION DIAGRAM FOR WAVES FROM THE SOUTH WITH AN 8 SECOND PERIOD.

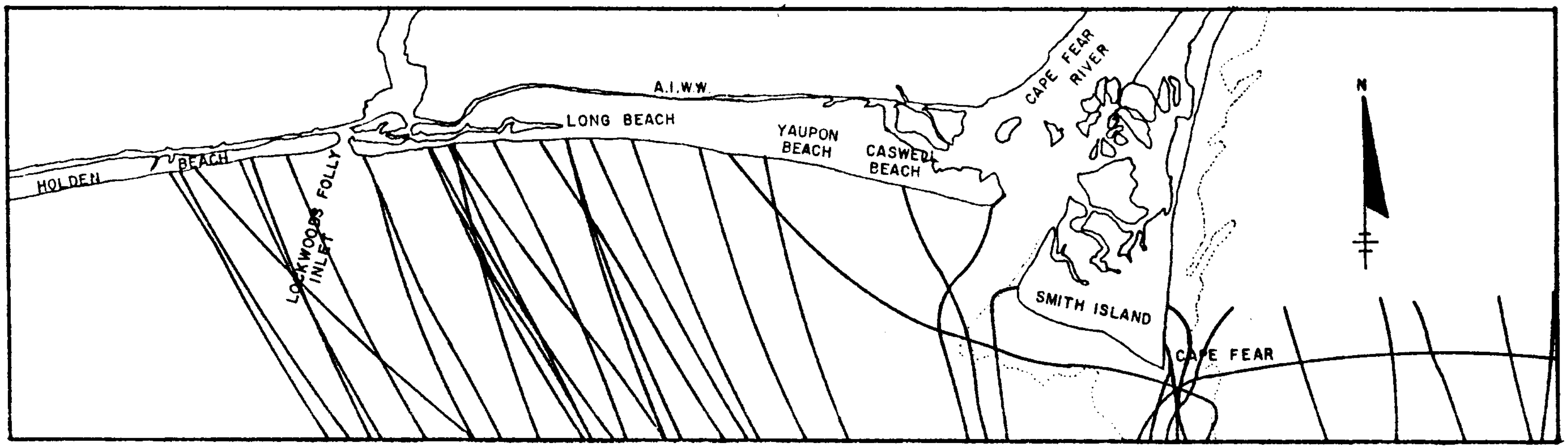


FIGURE 5

WAVE REFRACTION DIAGRAM FOR WAVES FROM EAST 60° SOUTH WITH AN 8 SECOND PERIOD.

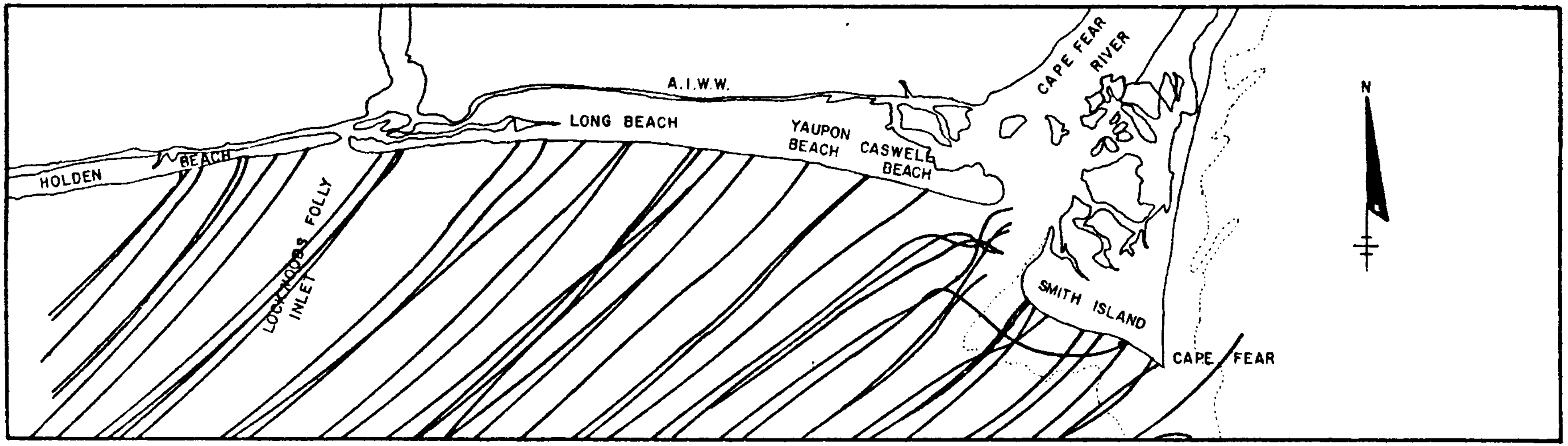


FIGURE 8

WAVE REFRACTION DIAGRAM FOR WAVES FROM SOUTH 60° WEST WITH AN 8 SECOND PERIOD.

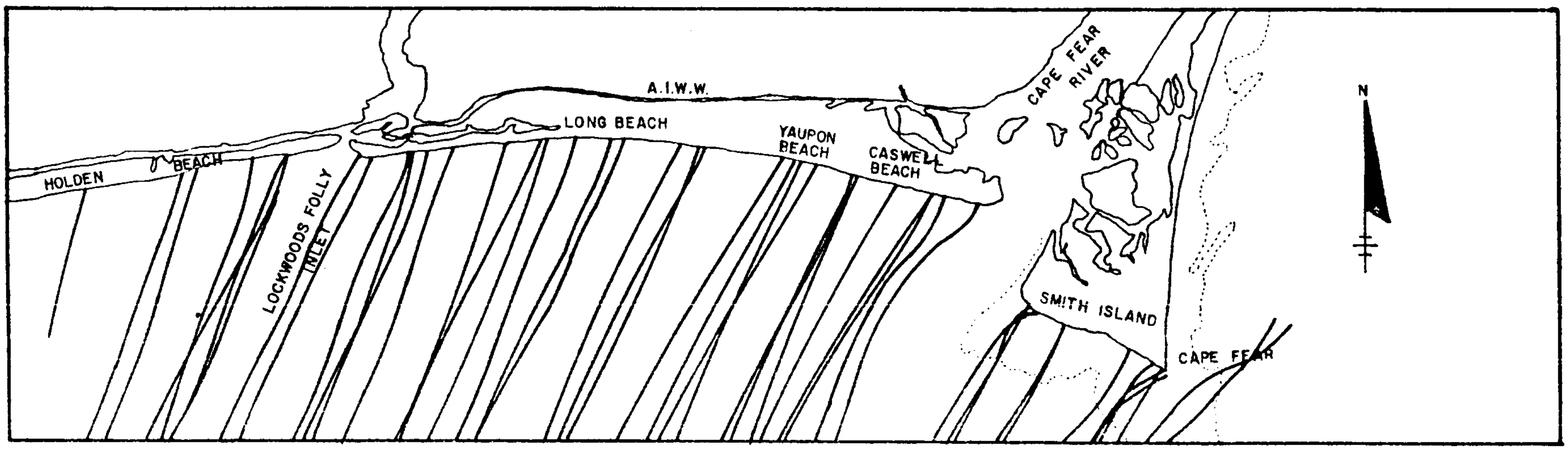


FIGURE 7

WAVE REFRACTION DIAGRAM FOR WAVES FROM SOUTH 30° WEST WITH AN 8 SECOND PERIOD.

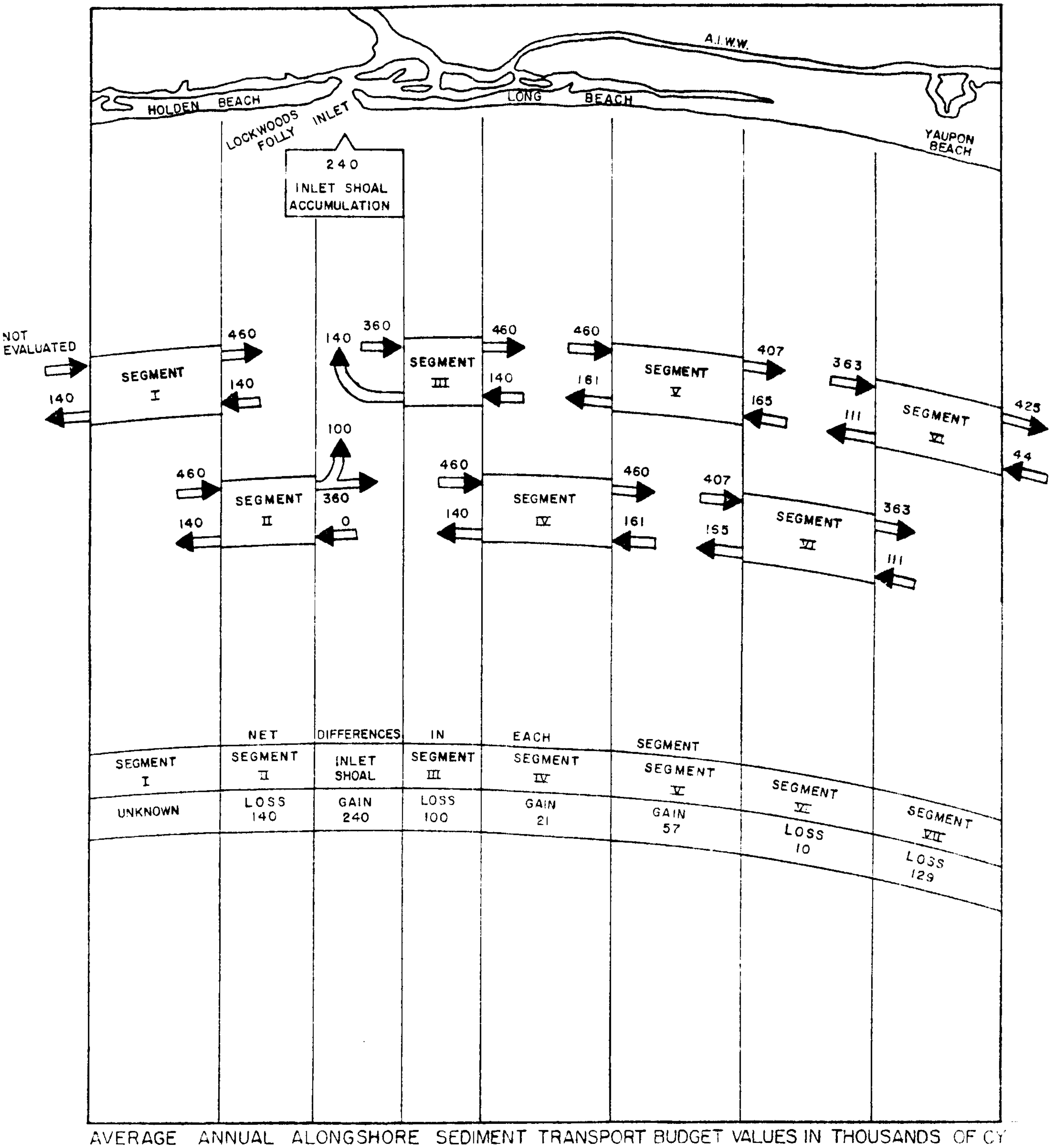
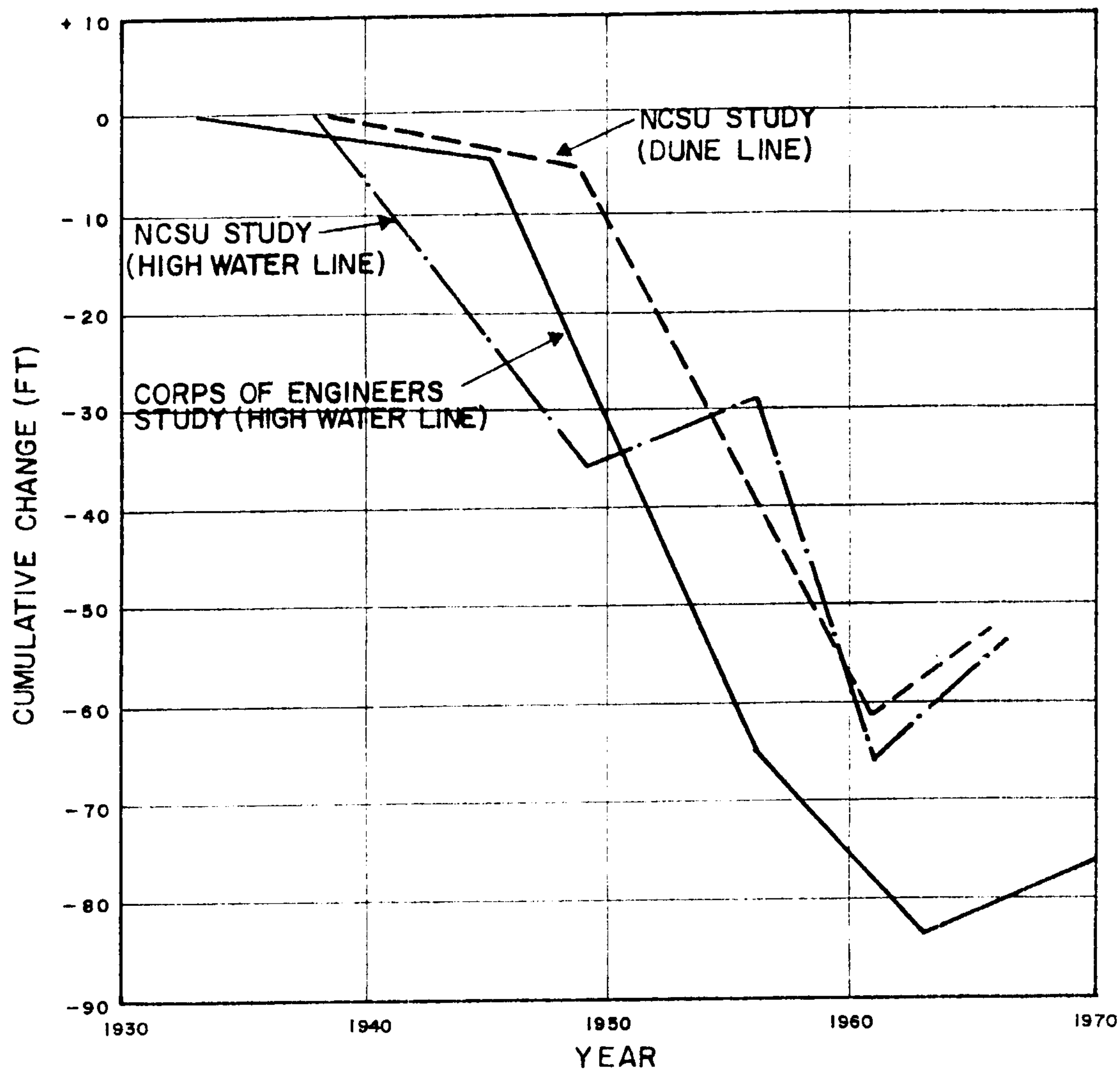


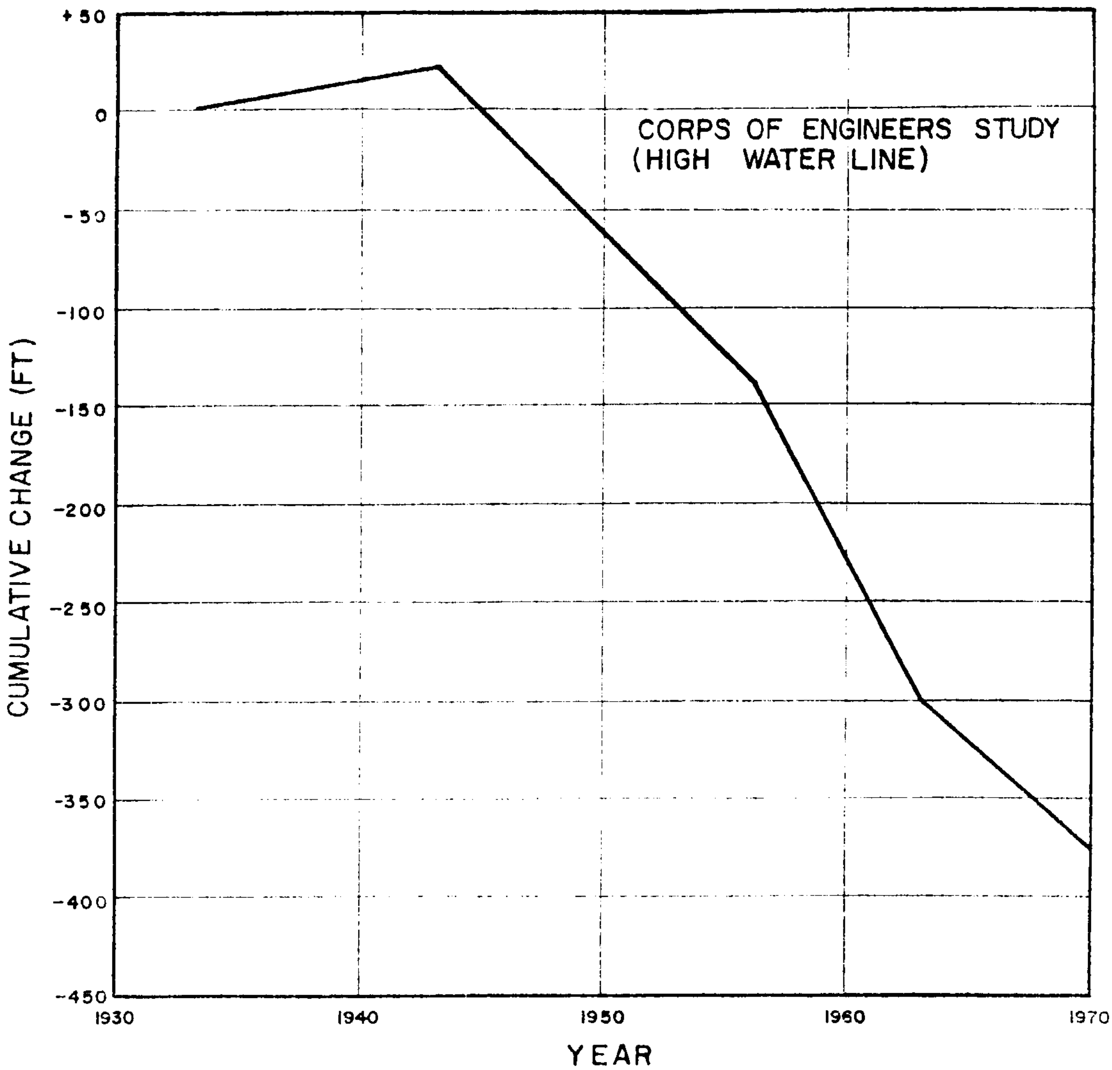
FIGURE 9
ALONGSHORE MATERIALTRANSPORT
(CONTINUITY ANALYSIS)



NOTE: NEGATIVE AND POSITIVE CUMULATIVE CHANGES REFER TO EROSION AND ACCRETION RESPECTIVELY.

FIGURE **10**.

CUMULATIVE SHORELINE CHANGES VS. TIME FOR HOLDEN BEACH BRUNSWICK COUNTY, NORTH CAROLINA.



NOTE:NEGATIVE AND POSITIVE CUMULATIVE CHANGES REFER TO EROSION AND ACCRETION RESPECTIVELY.

FIGURE **11**.

CUMULATIVE SHORELINE CHANGES VS. TIME FOR

EAST END HOLDENS BEACH

BRUNSWICK COUNTY, NORTH CAROLINA.

The groin is designed to build and maintain a protective beach by trapping littoral drift (beach material), or to retard the erosion of an existing beach. Although the groin is universally used, its functional behavior is not well understood. This situation has given rise to numerous variations in groin design (1). The groin design to be discussed herein is one of the latest and least expensive innovations to be introduced into the market with reputedly distinct advantages.

Generally, the groin is constructed perpendicular to the beach strand. The landward end extends to a point where it cannot be flanked by storm tide while the length of the seaward end depends on the width of beach strand to be stabilized. The structure is relatively narrow in width and varies in length depending on the beach characteristics. Classification of groins are given in Table 1.

TABLE 1. Classification of Groins

I) Classification:	Beach groin - a coastal structure usually built perpendicular to shoreline to trap littoral drift and thereby retard erosion of shore. Narrow in width with its length varying from less than 10 ft to several hundred feet. Stabilizes or restores or widens beach.
	Current breaker - a groin with primary purpose to intercept currents which cause movement of material along beach.
II) Type:	Nonadjustable - a fixed groin high enough to block most of normal littoral drift but low enough to allow over-topping by storm waves carrying sand over groin.
	Adjustable - groin with length and height adjustable.
	Impermeable - a solid or nearly solid structure preventing littoral drift passing through structure.
	Permeable - a groin with openings through structure of sufficient size to permit passage of littoral drift through openings.

According to Nagai (3) the groin should be oriented perpendicular to the shoreline when the waves approach the shoreline from an angle of 60° to 90°. If the waves approach the shoreline from an angle of 35° to 55° the groin should be oriented at an angle of 105° to 115° (exposed side to shoreline).

When a series of groins are constructed as a unit to protect the shoreline, they form a field or system. According to Nagai (4) the spacing between the groins in the system should be equal to three to four times the average length of the groins in the field.

The groin field functions are:

(1) To stabilize a beach subject to intermittent periods of advance and recession,

(2) To provide upland protection by preventing removal of a protective beach,

(3) To reduce the rate of littoral transport out of an area by orienting a section of the shoreline to an alignment more nearly perpendicular to the major direction of wave approach,

(4) To build or widen a beach by trapping littoral materials,

(5) To prevent loss of material out of an area by compartmentalizing the beach,

(6) To prevent accretion in a downdrift area by acting as a littoral barrier, and

(7) To stabilize a specific area by reducing the rate of loss.

From this list of benefits, it appears the groin is the ultimate solution to the erosion problem; however, improperly planned, designed and constructed groins have caused the use of groins to be widely disputed.

EROSION CONTROL PROJECT

In July, 1971, the Office of Water and Air Resources, North Carolina Department of Natural and Economic Resources received state funds for an experimental erosion control project. With limited funds ($50,000), an experimental sand-filled nylon bag groin field was planned, designed and constructed to provide positive erosion control.

SAND-FILLED NYLON BAG GROINS

The use of fabric bags filled with sand has long been employed successfully to direct or regulate the flow of water in river channels and to protect eroding river banks. The use of sand-filled fabric bags has gained wide acceptance in both the U.S. and Europe (5).

Technical Description of Nylon Bags. "Dura-Bags" patented by Erosion Control, Inc. of West Palm Beach, Florida were used in the Holden Beach project. The bags were fabricated from synthetic fiber material. Details of the fabric bags are given in Table 2.

TABLE 2. Fabric and Specifications.

I. Fabric Specifications:

Yarn - 840 Denier, high tenacity continuous filament, first quality nylon.

Fabric Construction - 22 Ends per inch finished (±1)
22 Picks per inch finished (±1)

Weave - Plain - Rip - Stop
Rip-Stop on 6 ends and 6 picks

Tensile Grab - 325 pounds × 325 minimum

Finish - Polyvinyl Chloride

Weight - 10.5 ounces per square yard (±1 ounce)

Porosity - 30 to 40 cfm

II. Bag Fabrication:

Self-Sealing: No end seams. Side seams are placket folded and sewn with a double needle lockstitch. Self-Sealing opening located within one third of either end of the bag. Self-Sealing opening with overlap flap sewn with a double needle lockstitch.

III. Sewing Thread Specification:

A monocord construction of polyester fiber with a melting point above 482 degrees. Physical characteristics are:

Tensile Strength	17 lbs. minimum
Elongation	10 15%
Yards per pound	3800 minimum
Finish:	
Ether-extractable	11.5± 1.5%
Alcohol (after ether extraction)	4± .75%
Total Finish	15.5± 2.25%

Unfilled, the bags are 5 ft by 10 ft and weigh approximately 5¼ lbs. When filled, the bags hold 2½ cubic yards of material and are approximately 9½ by 4½ by 1½ ft.

DESIGN AND CONSTRUCTION OF SAND-FILLED NYLON BAG GROINS

Pilot Groin. To determine the direction and relative magnitude of the net littoral drift and to afford the state road on the east end of the island some measure of protection, a pilot groin was constructed in July 1971. A low impermeable structure with two nylon bags in the base and one nylon bag interlocking on the top (Figure 12) was designed to stabilize the beach near the end of the state road. The pilot groin was designed to follow the natural slope of the beach from Elev. + 5.0 ft (2.0 ft above high tide) to Elev. -3.0 ft (1.0 ft below low tide). This design allowed sand to pass over the top of the structure at high tide thus preventing excessive scour on the downdrift side.

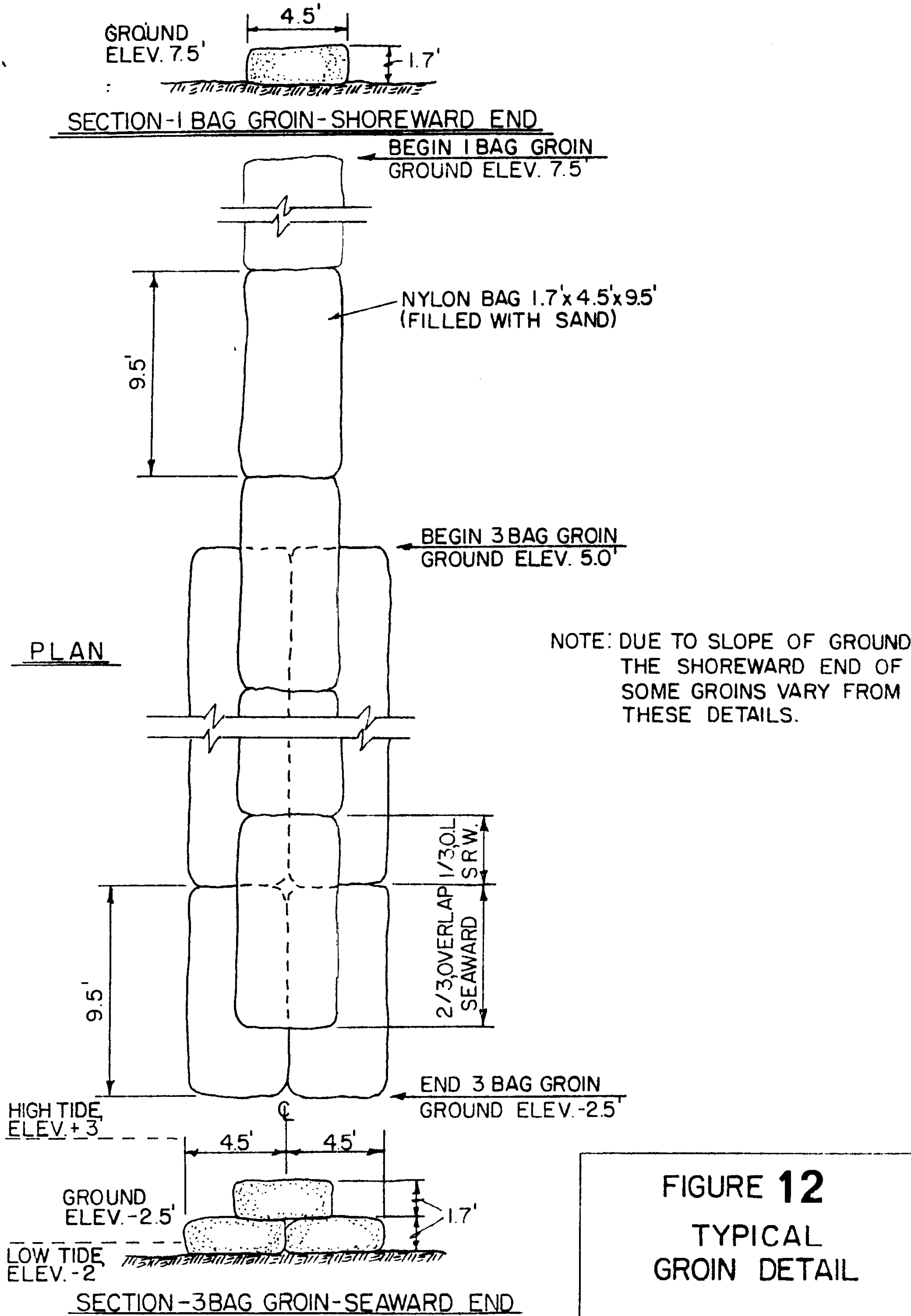


FIGURE 12

TYPICAL GROIN DETAIL

The pilot groin was constructed by Coastal Erosion Control of Greenville, N.C. The nylon bags were hydraulically filled in place with available beach sand. A 3 in. centrifugal bilge pump was used to dredge sand from the beach (Figure 13). Each bag was filled with approximately 7000 lbs. of beach sand. Eighty-four sand-filled nylon bags (65 bags in the base; 19 bags in the top) were used in the construction of the 265 ft groin (Figure 13). The total cost of the pilot structure was $3,360 ($40/bag).

Experimental Groin Field. To stabilize the east end of the beach, an experimental groin field of 15 nylon bag groins (Figure 14) was constructed between July and September 1972. Low impermeable structures were designed to stabilize 4000 ft of beach front. The groins were designed to follow the natural slope of the beach. The shoreward ends from Elev. + 7.5 ft (4.5 ft above high tide) to Elev. + 1.0 ft (2.0 ft above low tide) were designed to use one (sometimes two) nylon bags. The shoreward end of the structure was designed to maintain integrity with either an existing timber bulkhead or a sand dune. The shoreward end trapped the sand transported along the beach strand by wind. The seaward ends from Elev. + 1.0 ft (2.0 ft above low tide) to Elev. -3.0 ft (1.0 ft below low tide) were designed to use two bags in the base with one bag interlocking on top similar to the pilot groin to by-pass sand over the top of the structure at high tide thus preventing excessive scour on the downdrift side of the structures. The lengths, spacing and other pertinent data are given in Table 3.

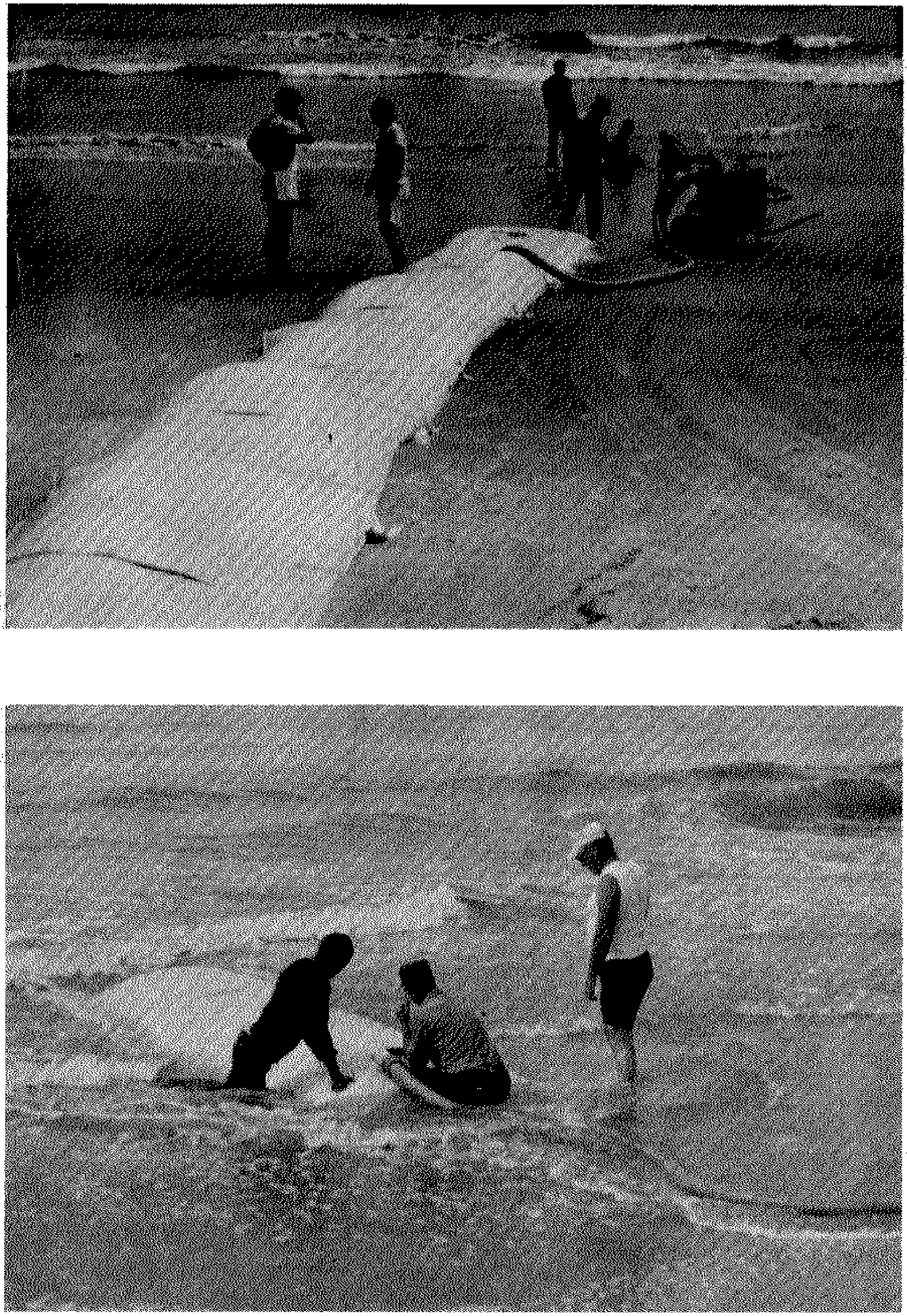


Figure 13. Sand-Filling Operation.

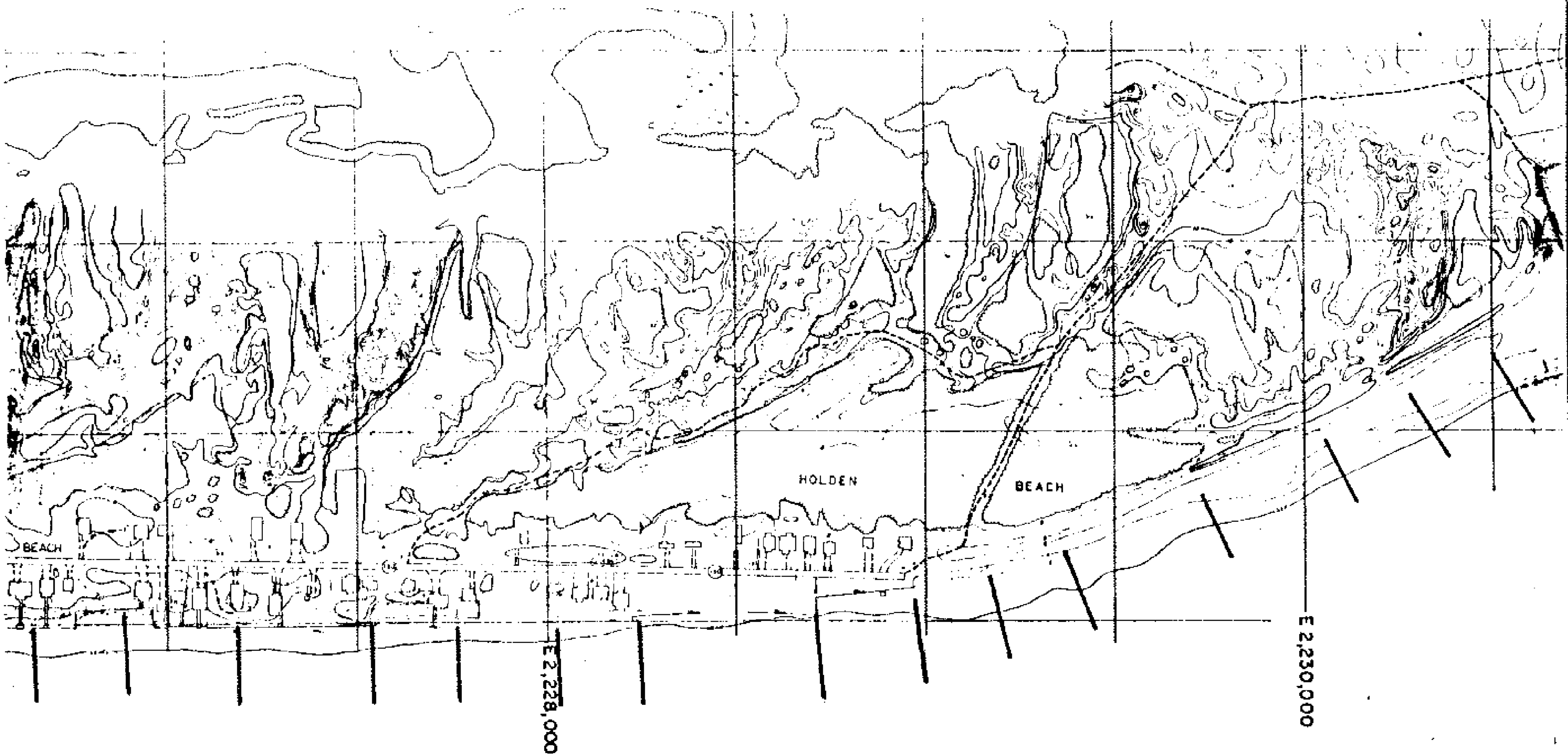


FIGURE **14**
HOLDEN BEACH
SHORELINE TOPOGRAPHY

TABLE 3. Nylon-Bag Groin Field.

Groin No.	Length Overall (ft)	No. of Bags	Spacing Between Groins (ft)	Remarks
1	190.0	50	245	
2	237.5	59	300	
3	190.0	51	350	
4	190.0	56	235	
5	152.0	48	235	
6	142.5	45	225	
7	180.5	57	250	
7A	265.0	84	235	Pilot Groin
8	237.5	65	225	
9	266.5	80	210	
10	285.0	84	230	
11	275.5	81	375	
12	209.0	66	350	
13	190.0	60	260	
14	199.0	57	225	
15	228.0	66		

The groins were constructed normal to the shoreline. The total cost of the groin field was $43,550 ($43.50/bag).

EVALUATION OF SAND-FILLED NYLON BAG GROINS

FUNCTIONAL EFFECTIVENESS

To determine the functional effectiveness of the groin field, beach profiles were taken at groins No. 1 through 15 (See Figures 15 through 77). A significant accretion of material was experienced on the east side of groin No. 1 (see Figure 78, bottom picture). Accretion of material was experienced on both sides of groin No. 7A (due to wave refraction at the inlet) (See Figure 78, top picture). In August 1971, approximately 60,000 yd^3 (45,873 m^3) of dredge material from the intracoastal waterway and Lockwoods Folly Inlet was deposited on the beach approximately 2000 ft (619 m) from the east end of the beach. The groins were beneficial

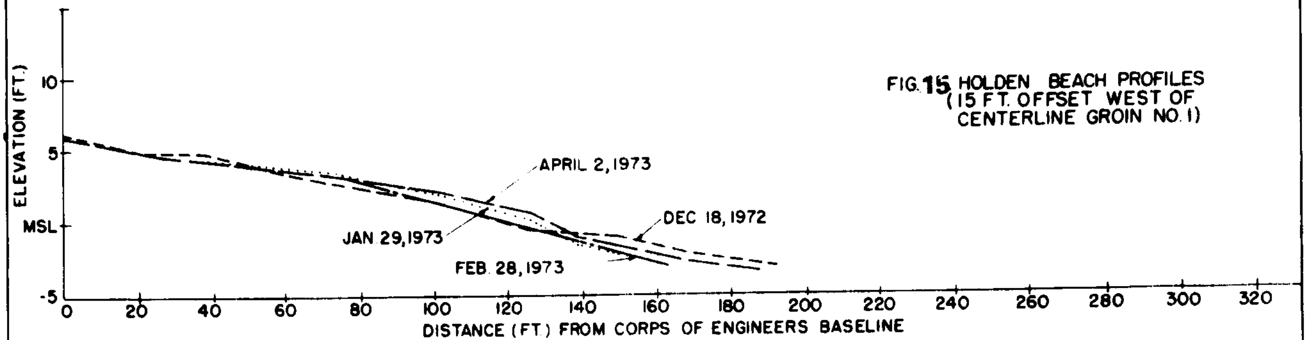


FIG. 15 HOLDEN BEACH PROFILES (15 FT. OFFSET WEST OF CENTERLINE GROIN NO. 1)

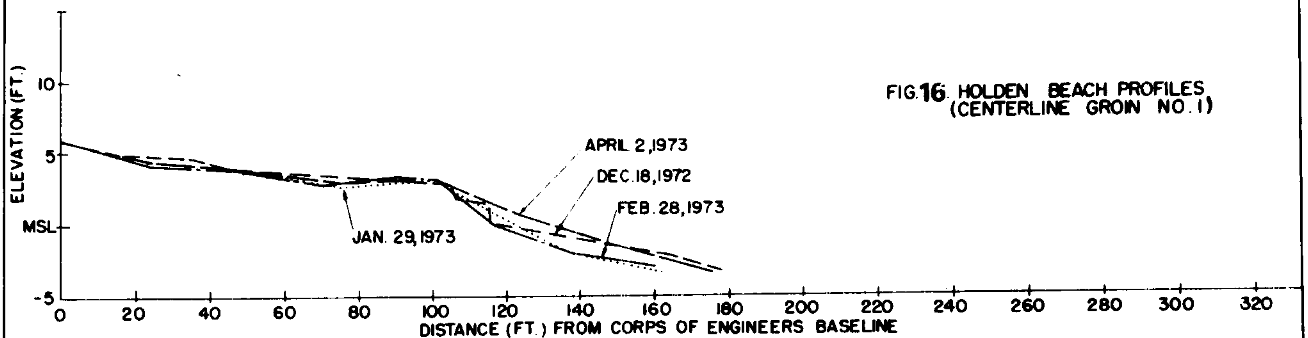


FIG. 16. HOLDEN BEACH PROFILES (CENTERLINE GROIN NO. 1)

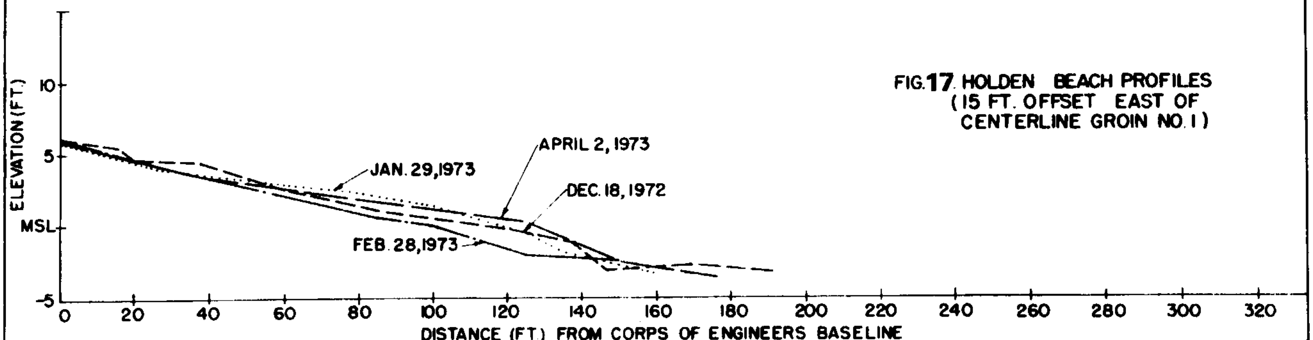


FIG. 17 HOLDEN BEACH PROFILES (15 FT. OFFSET EAST OF CENTERLINE GROIN NO. 1)

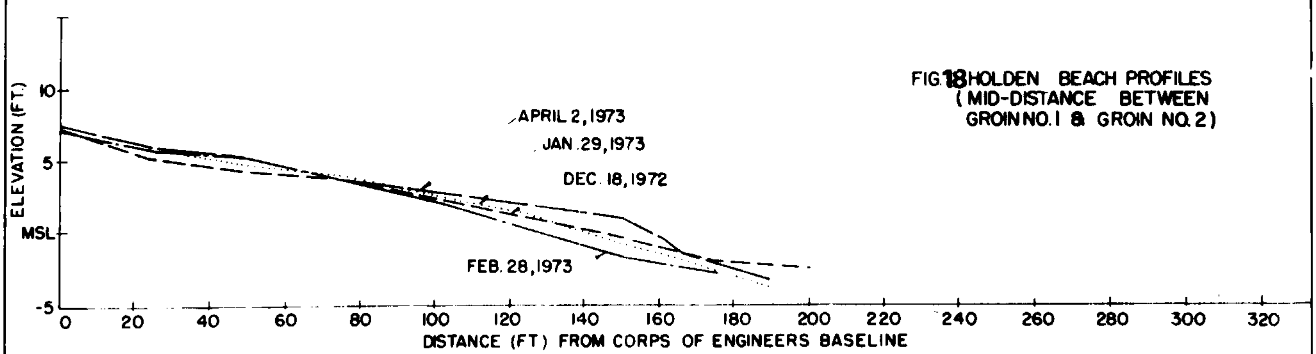


FIG. 18 HOLDEN BEACH PROFILES (MID-DISTANCE BETWEEN GROIN NO. 1 & GROIN NO. 2)

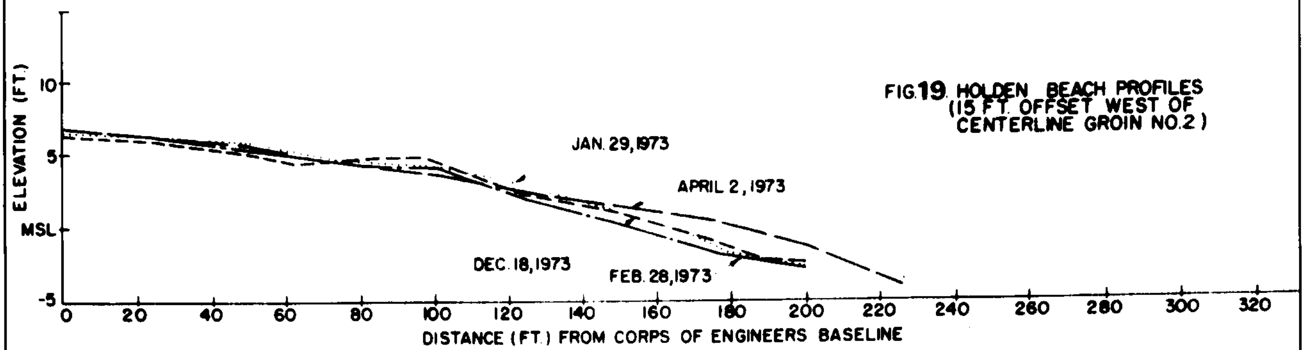


FIG. 19. HOLDEN BEACH PROFILES (15 FT. OFFSET WEST OF CENTERLINE GROIN NO. 2)

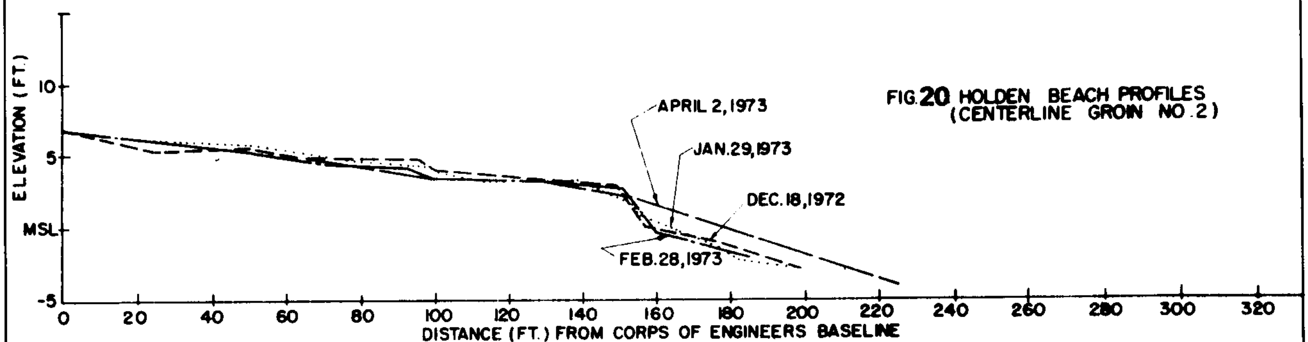


FIG. 20. HOLDEN BEACH PROFILES (CENTERLINE GROIN NO. 2)

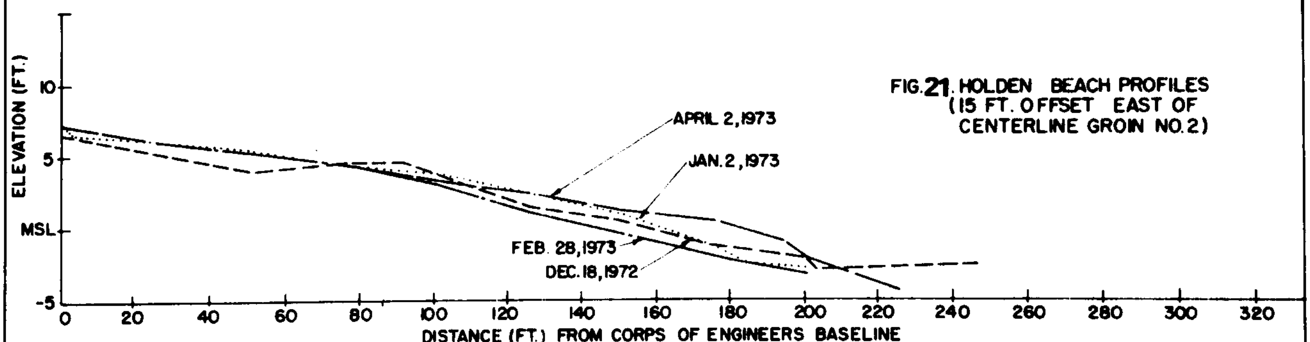


FIG. 21. HOLDEN BEACH PROFILES (15 FT. OFFSET EAST OF CENTERLINE GROIN NO. 2)

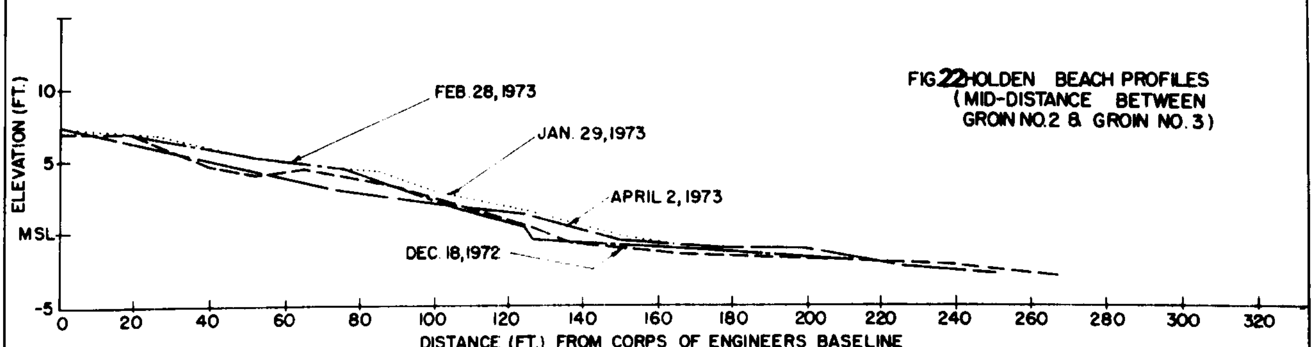


FIG. 22. HOLDEN BEACH PROFILES (MID-DISTANCE BETWEEN GROIN NO. 2 & GROIN NO. 3)

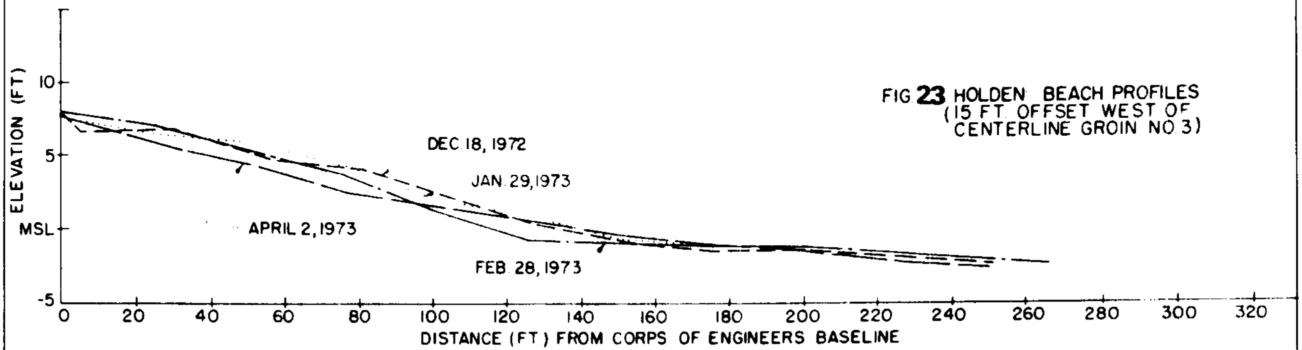


FIG 23 HOLDEN BEACH PROFILES (15 FT OFFSET WEST OF CENTERLINE GROIN NO 3)

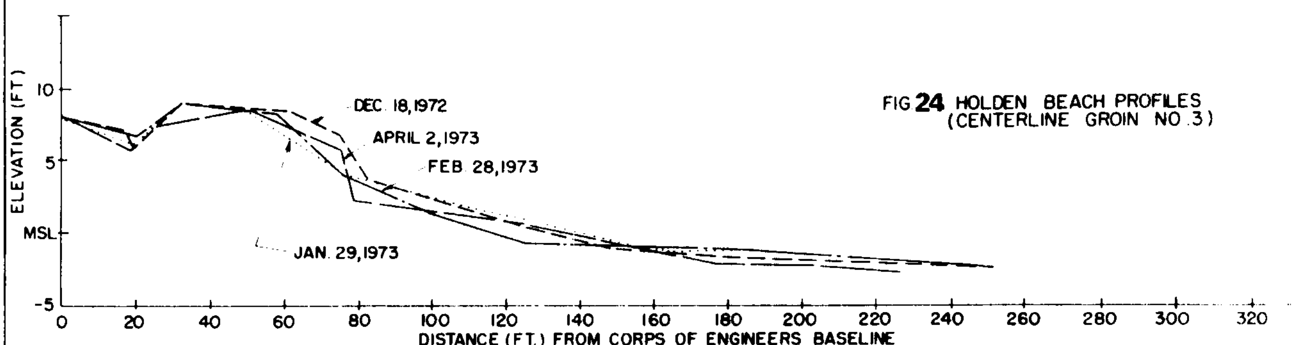


FIG 24 HOLDEN BEACH PROFILES (CENTERLINE GROIN NO 3)

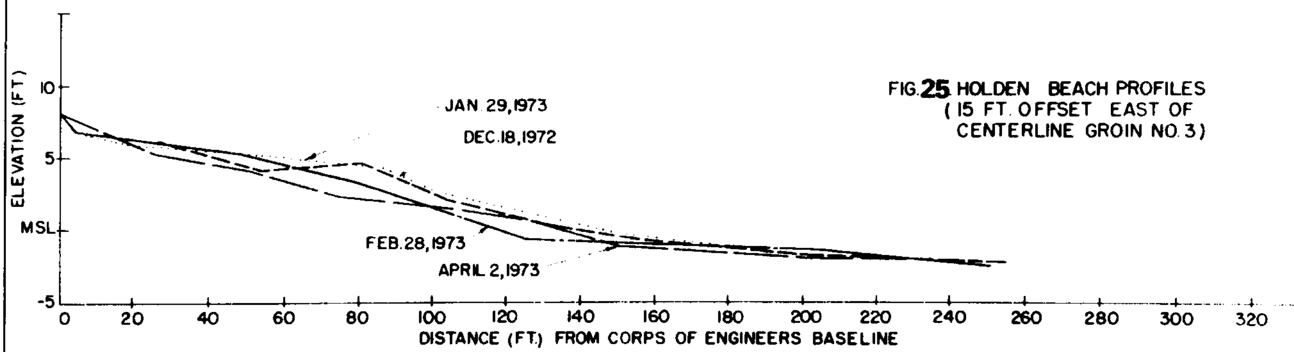


FIG. 25 HOLDEN BEACH PROFILES (15 FT. OFFSET EAST OF CENTERLINE GROIN NO. 3)

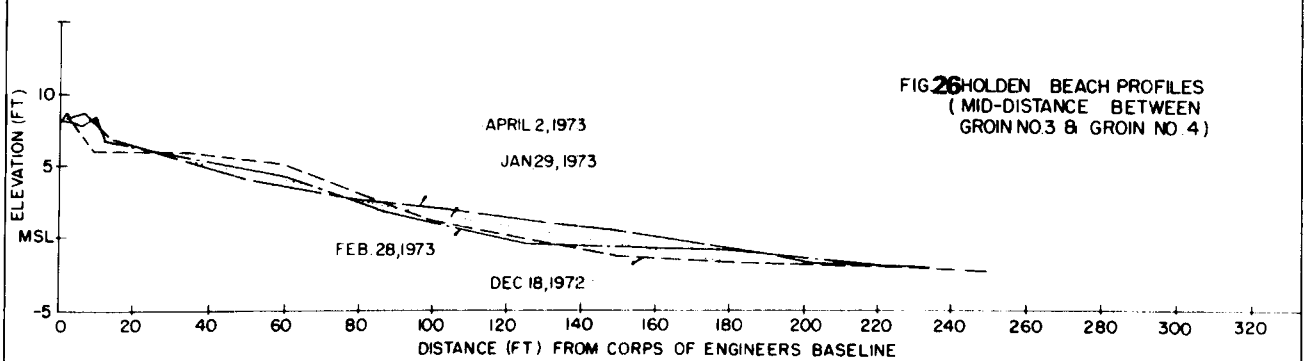


FIG. 26 HOLDEN BEACH PROFILES (MID-DISTANCE BETWEEN GROIN NO.3 & GROIN NO. 4)

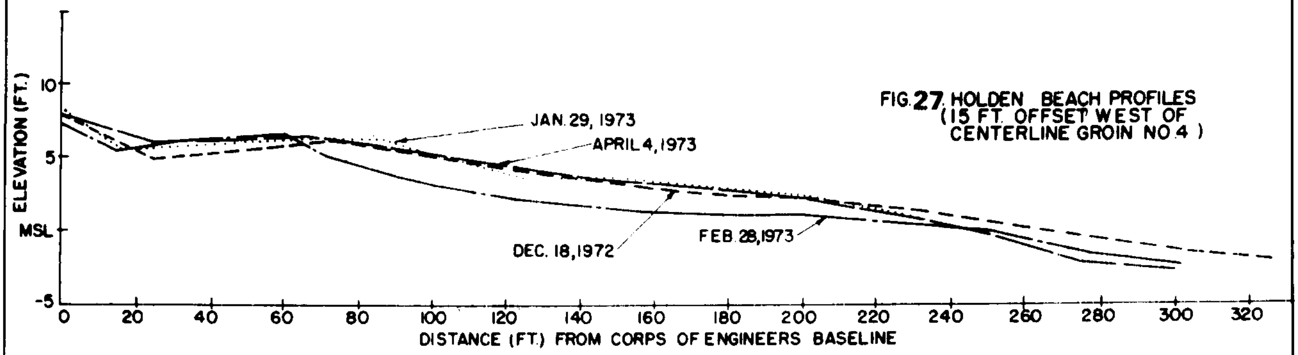


FIG. 27 HOLDEN BEACH PROFILES (15 FT. OFFSET WEST OF CENTERLINE GROIN NO. 4)

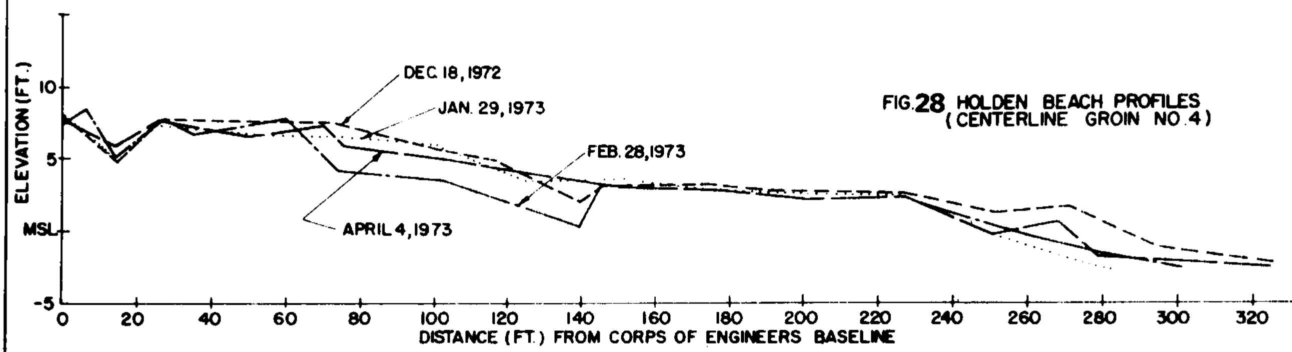


FIG. 28 HOLDEN BEACH PROFILES (CENTERLINE GROIN NO. 4)

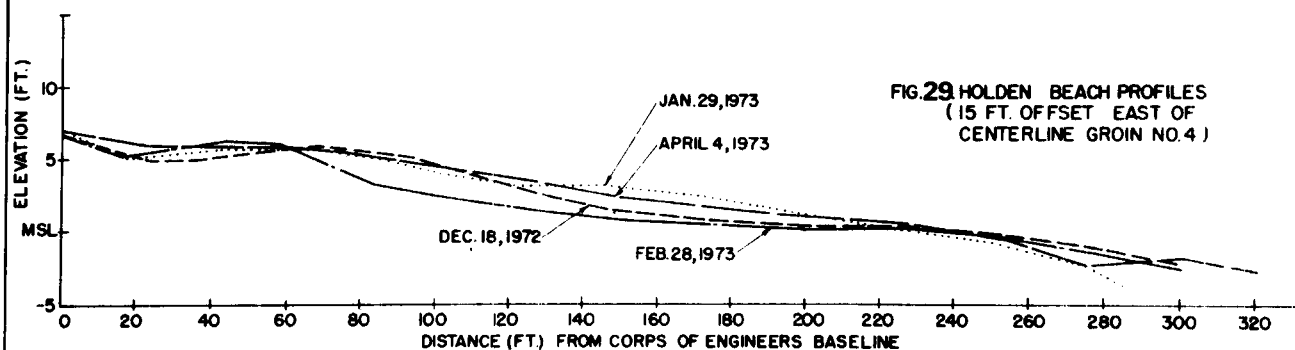


FIG. 29 HOLDEN BEACH PROFILES (15 FT. OFFSET EAST OF CENTERLINE GROIN NO. 4)

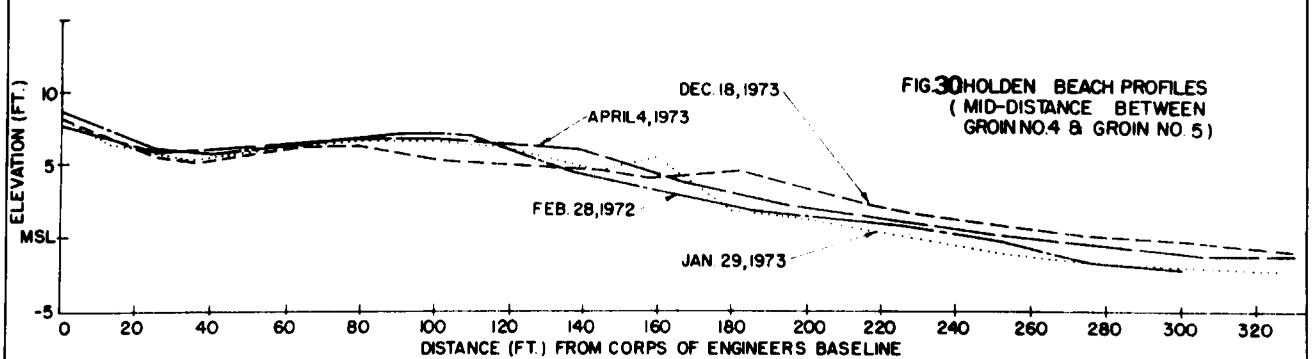


FIG. 30 HOLDEN BEACH PROFILES (MID-DISTANCE BETWEEN GROIN NO. 4 & GROIN NO. 5)

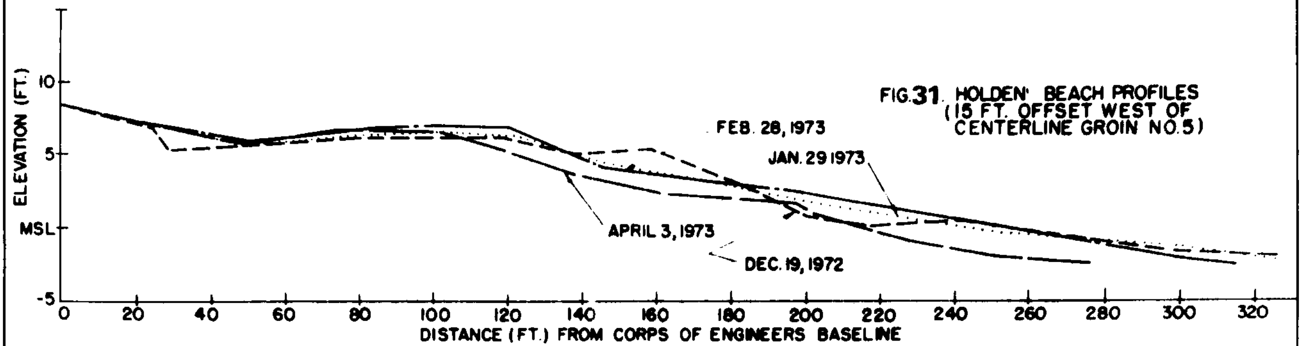


FIG. 31. HOLDEN BEACH PROFILES (15 FT. OFFSET WEST OF CENTERLINE GROIN NO. 5)

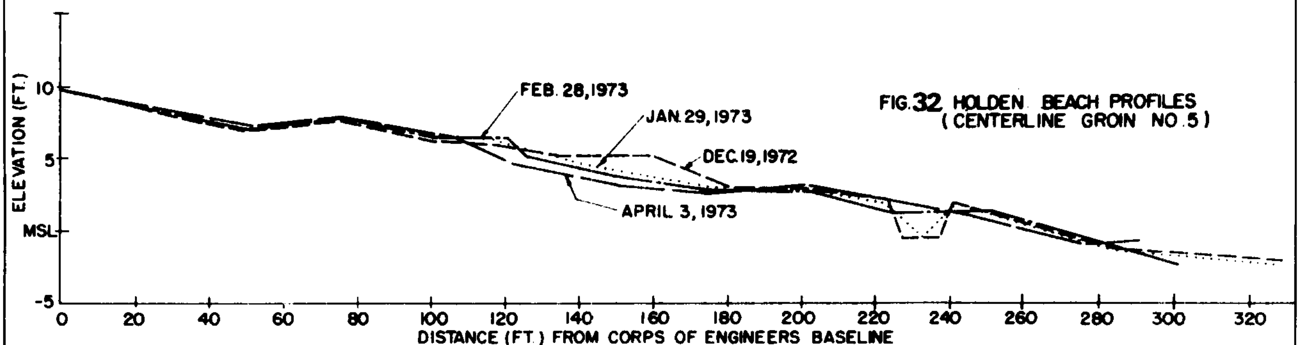


FIG. 32 HOLDEN BEACH PROFILES (CENTERLINE GROIN NO. 5)

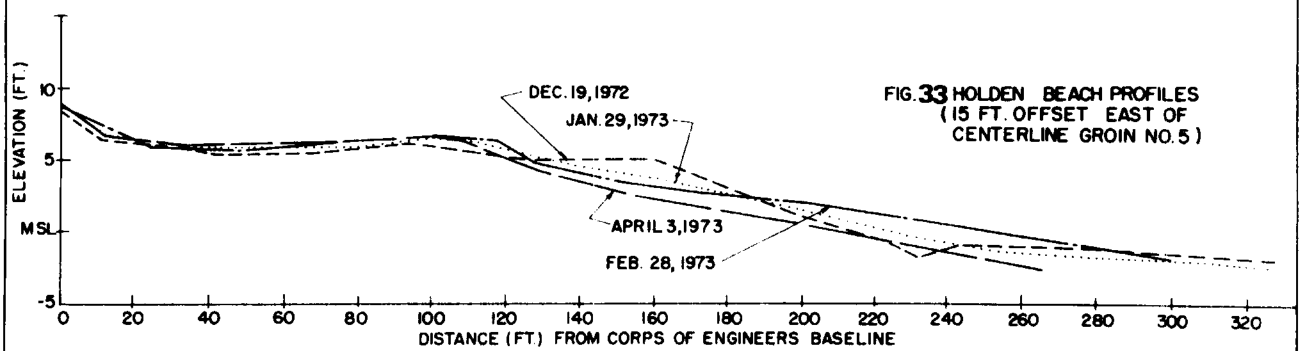


FIG. 33 HOLDEN BEACH PROFILES (15 FT. OFFSET EAST OF CENTERLINE GROIN NO. 5)

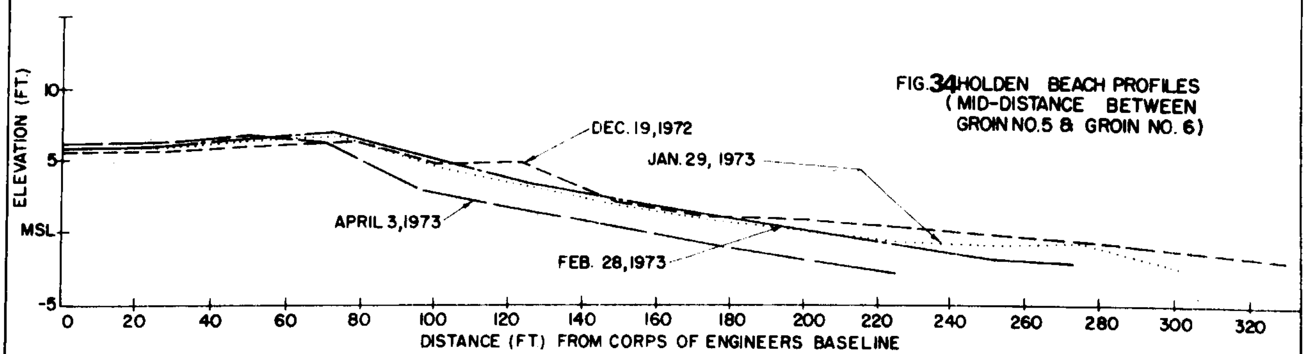


FIG. 34 HOLDEN BEACH PROFILES (MID-DISTANCE BETWEEN GROIN NO. 5 & GROIN NO. 6)

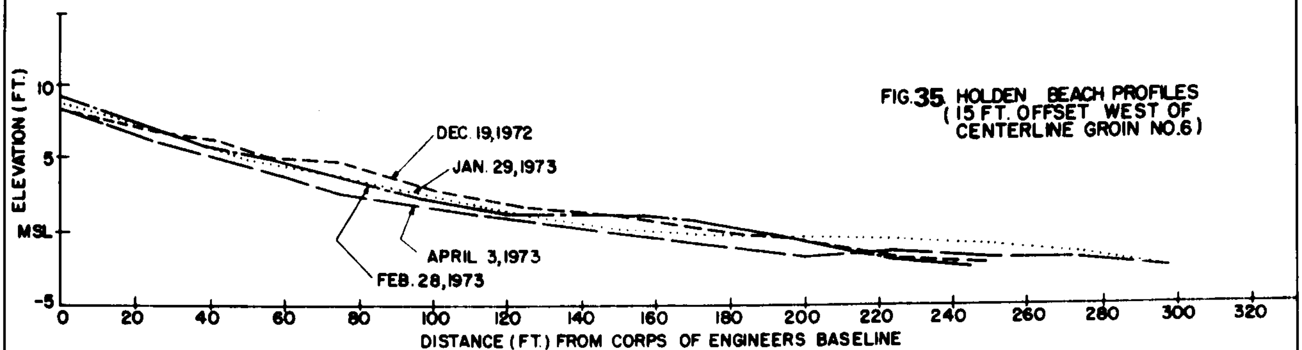


FIG. 35 HOLDEN BEACH PROFILES
(15 FT. OFFSET WEST OF CENTERLINE GROIN NO.6)
DEC. 19,1972
JAN. 29,1973
APRIL 3,1973
FEB. 28,1973
ELEVATION (FT.)
10
5
MSL
-5
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320
DISTANCE (FT.) FROM CORPS OF ENGINEERS BASELINE

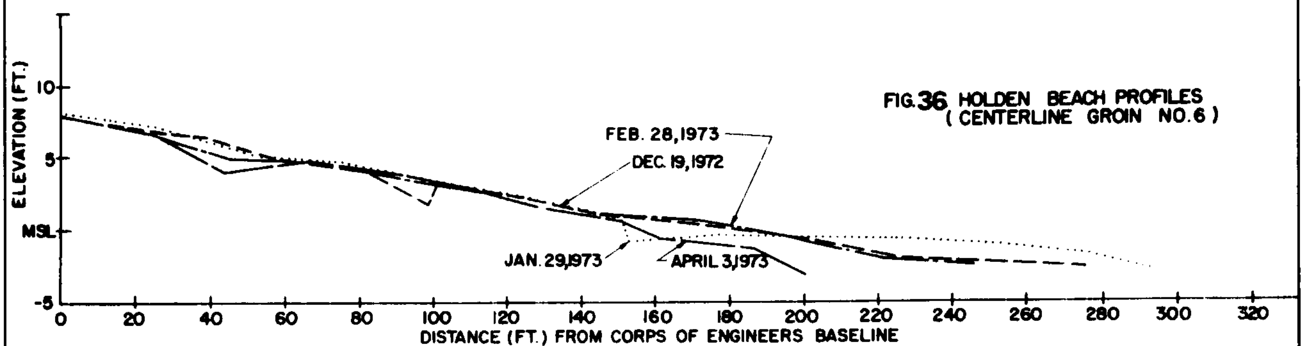


FIG. 36 HOLDEN BEACH PROFILES
(CENTERLINE GROIN NO. 6)
FEB. 28,1973
DEC. 19,1972
JAN. 29,1973
APRIL 3,1973
ELEVATION (FT.)
10
5
MSL
-5
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320
DISTANCE (FT.) FROM CORPS OF ENGINEERS BASELINE

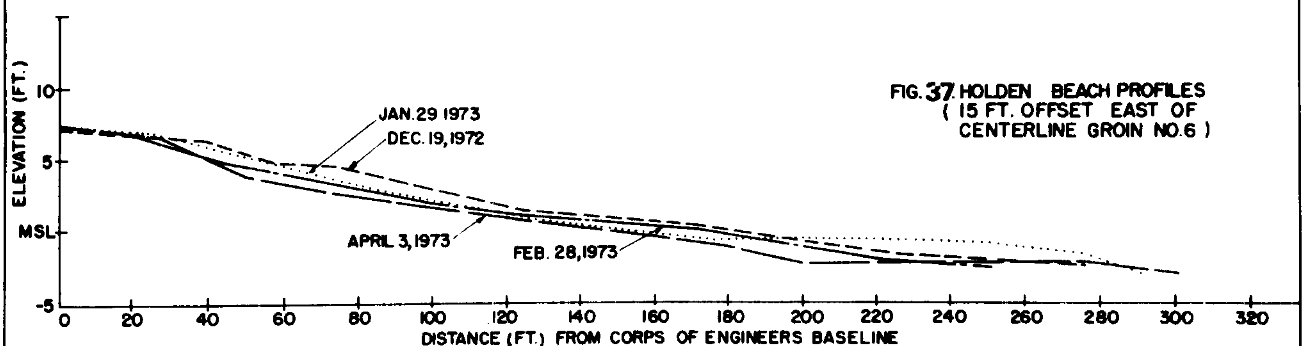


FIG. 37 HOLDEN BEACH PROFILES
(15 FT. OFFSET EAST OF CENTERLINE GROIN NO.6)
JAN.29 1973
DEC. 19,1972
APRIL 3,1973
FEB. 28,1973
ELEVATION (FT.)
10
5
MSL
-5
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320
DISTANCE (FT.) FROM CORPS OF ENGINEERS BASELINE

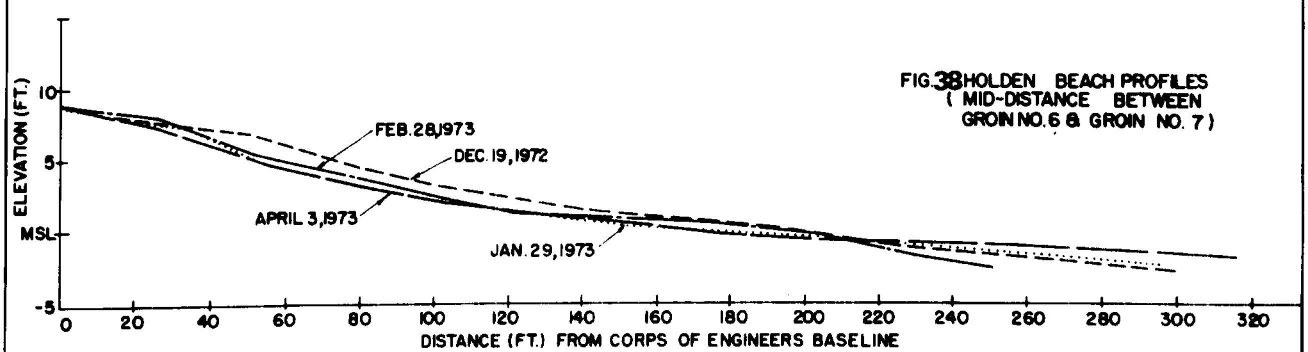


FIG. 38 HOLDEN BEACH PROFILES
(MID-DISTANCE BETWEEN GROIN NO.6 & GROIN NO. 7)
FEB.28,1973
DEC. 19,1972
APRIL 3,1973
JAN. 29,1973
ELEVATION (FT.)
10
5
MSL
-5
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320
DISTANCE (FT.) FROM CORPS OF ENGINEERS BASELINE

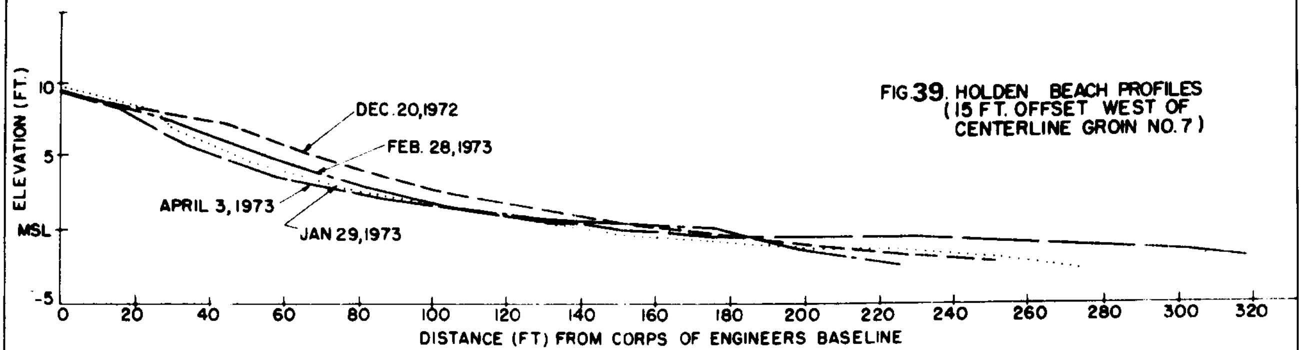


FIG. 39. HOLDEN BEACH PROFILES (15 FT. OFFSET WEST OF CENTERLINE GROIN NO. 7)

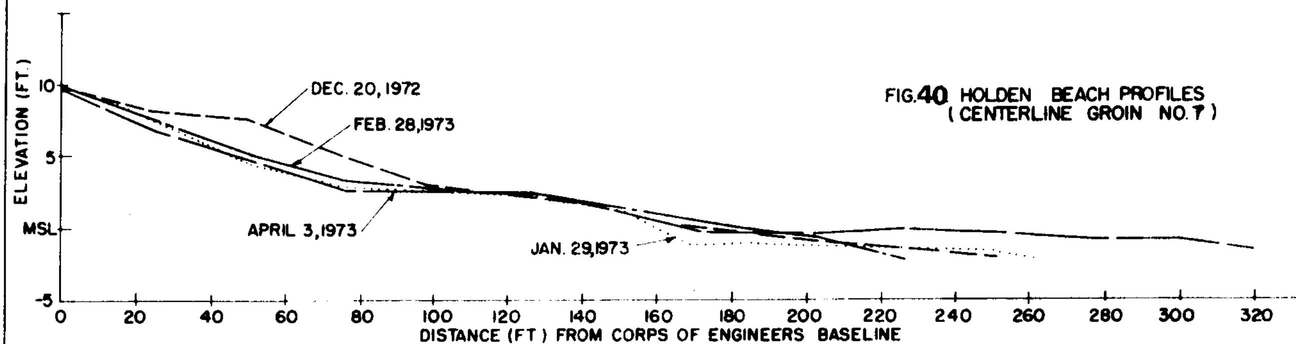


FIG. 40 HOLDEN BEACH PROFILES (CENTERLINE GROIN NO. 7)

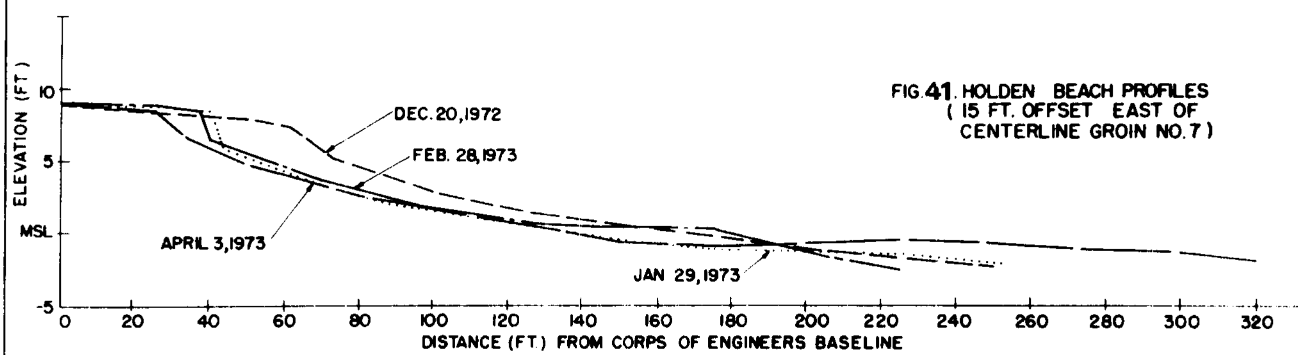


FIG. 41. HOLDEN BEACH PROFILES (15 FT. OFFSET EAST OF CENTERLINE GROIN NO. 7)

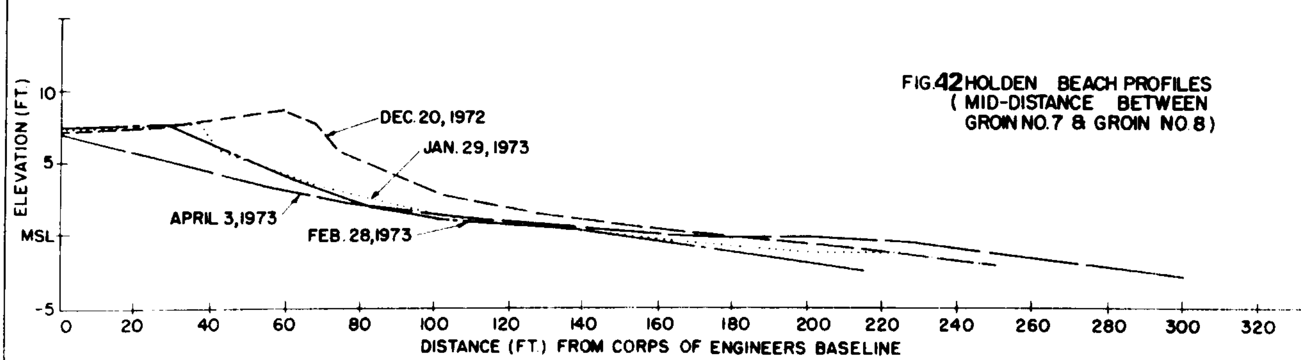


FIG. 42 HOLDEN BEACH PROFILES (MID-DISTANCE BETWEEN GROIN NO. 7 & GROIN NO. 8)

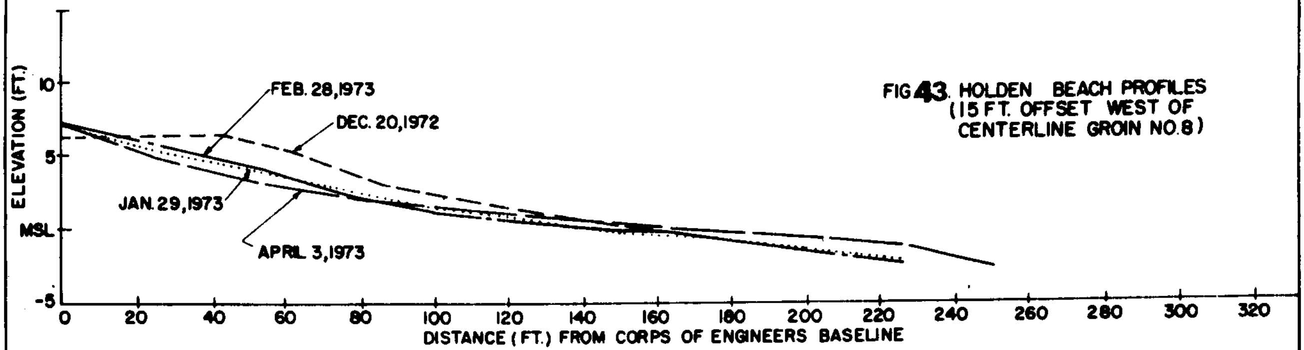


FIG 43. HOLDEN BEACH PROFILES (15 FT. OFFSET WEST OF CENTERLINE GROIN NO. 8)

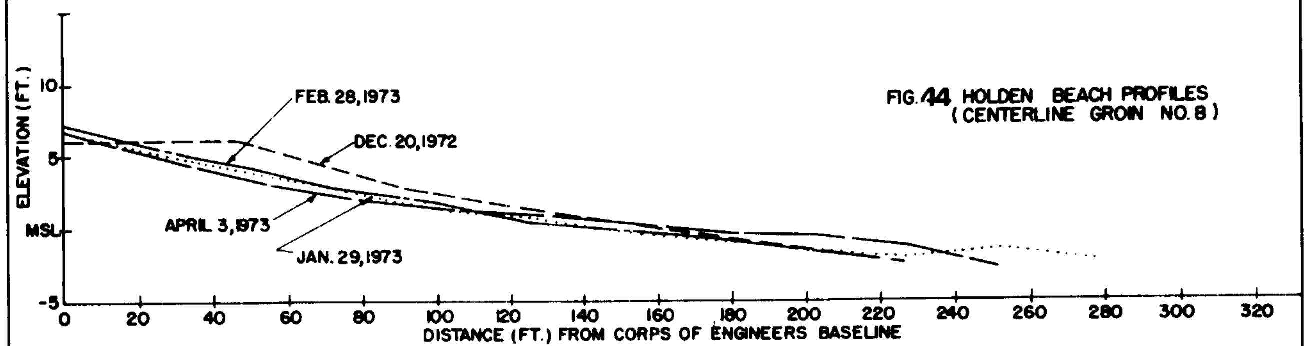


FIG. 44 HOLDEN BEACH PROFILES (CENTERLINE GROIN NO. 8)

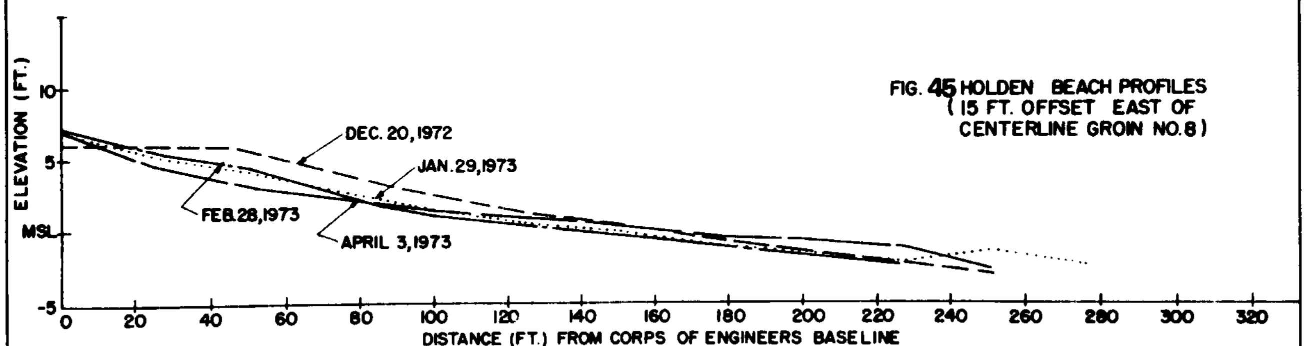


FIG. 45 HOLDEN BEACH PROFILES (15 FT. OFFSET EAST OF CENTERLINE GROIN NO. 8)

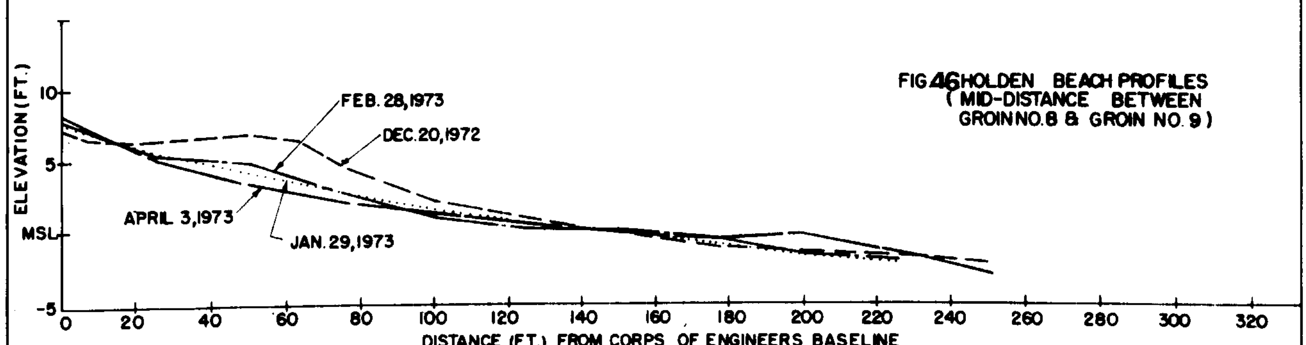


FIG 46 HOLDEN BEACH PROFILES (MID-DISTANCE BETWEEN GROIN NO. 8 & GROIN NO. 9)

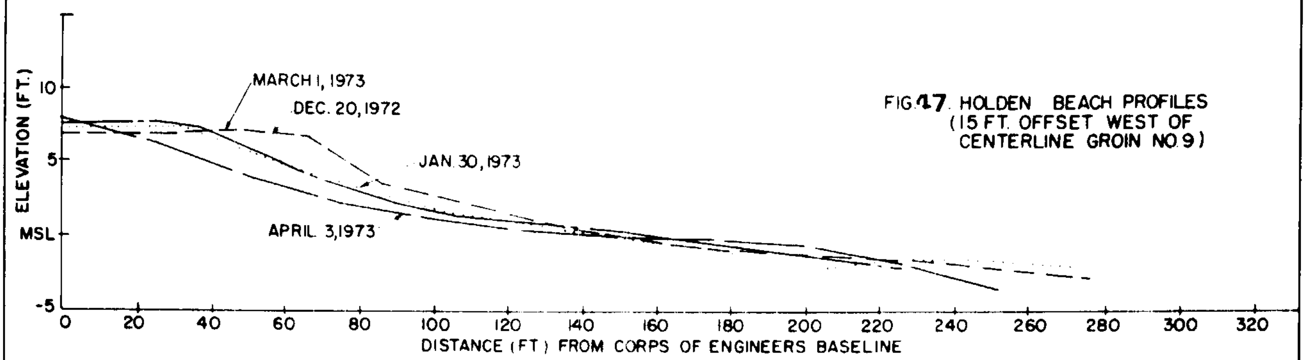


FIG. 47. HOLDEN BEACH PROFILES (15 FT. OFFSET WEST OF CENTERLINE GROIN NO. 9)

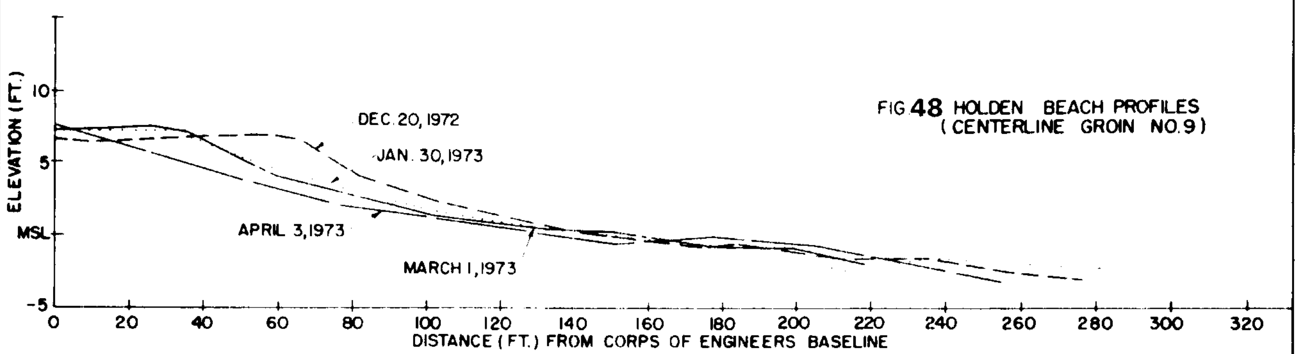


FIG 48 HOLDEN BEACH PROFILES (CENTERLINE GROIN NO. 9)

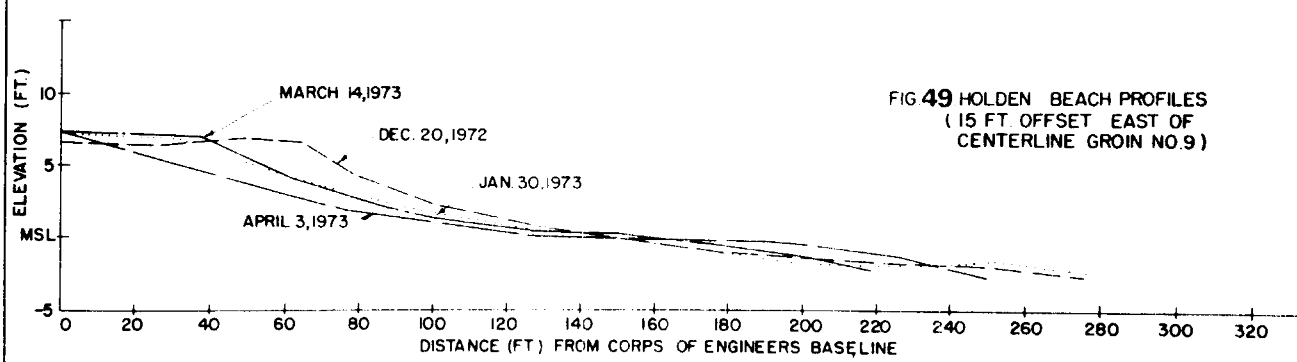


FIG 49 HOLDEN BEACH PROFILES (15 FT. OFFSET EAST OF CENTERLINE GROIN NO. 9)

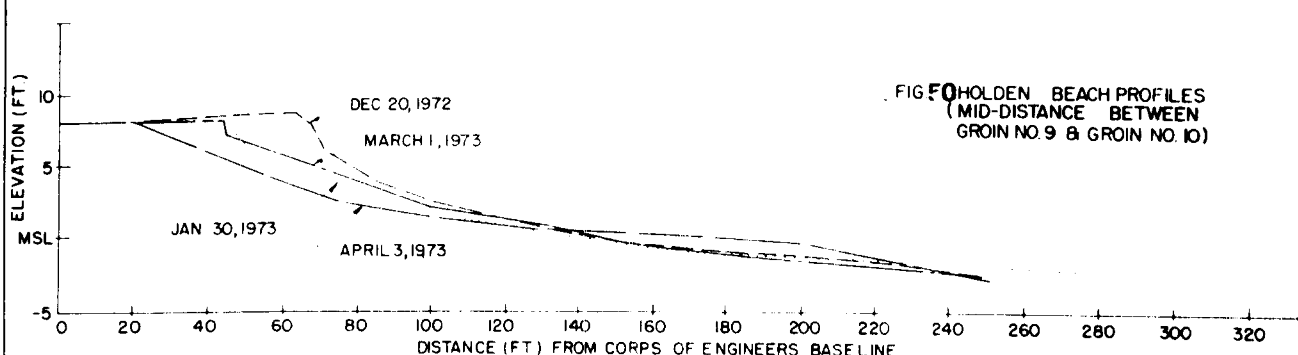


FIG 50 HOLDEN BEACH PROFILES (MID-DISTANCE BETWEEN GROIN NO. 9 & GROIN NO. 10)

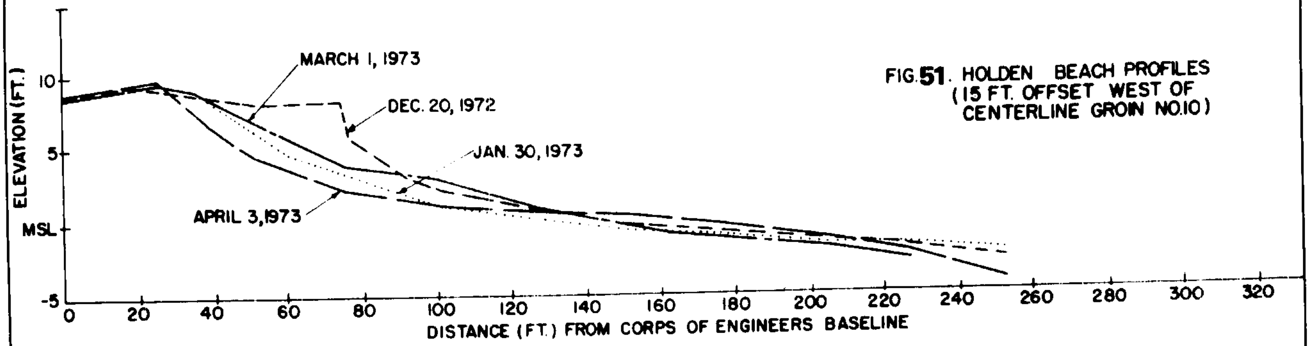


FIG. 51. HOLDEN BEACH PROFILES (15 FT. OFFSET WEST OF CENTERLINE GROIN NO.10)

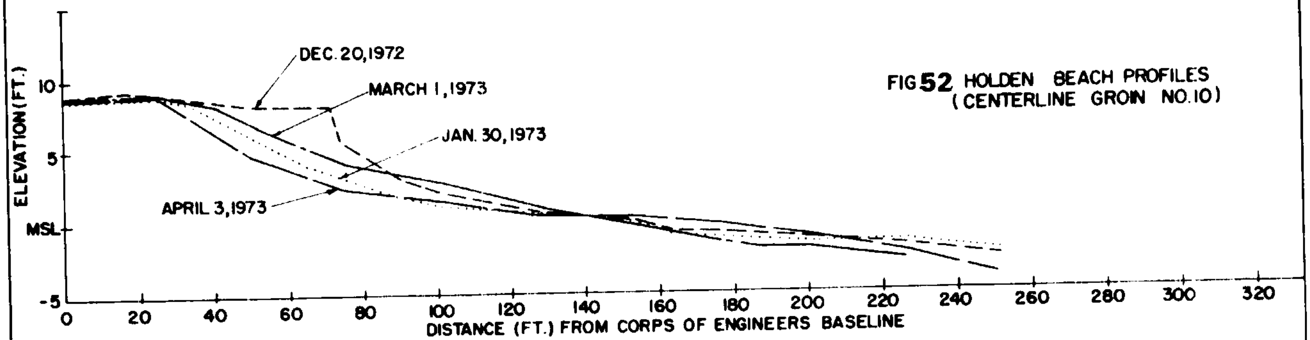


FIG 52 HOLDEN BEACH PROFILES (CENTERLINE GROIN NO.10)

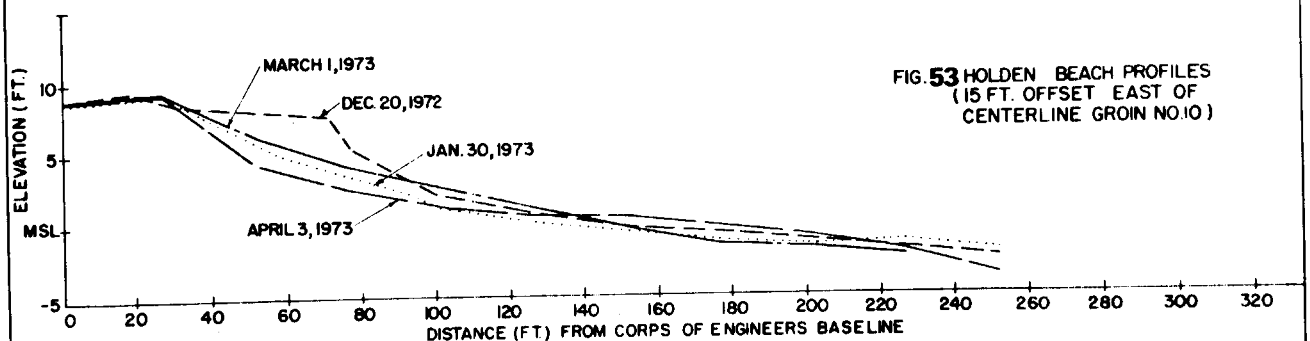


FIG. 53 HOLDEN BEACH PROFILES (15 FT. OFFSET EAST OF CENTERLINE GROIN NO.10)

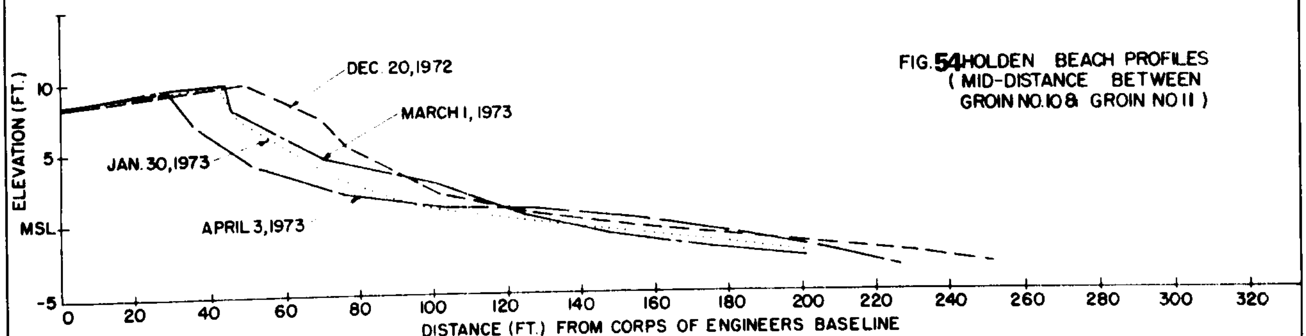


FIG. 54 HOLDEN BEACH PROFILES (MID-DISTANCE BETWEEN GROIN NO.10 & GROIN NO 11)

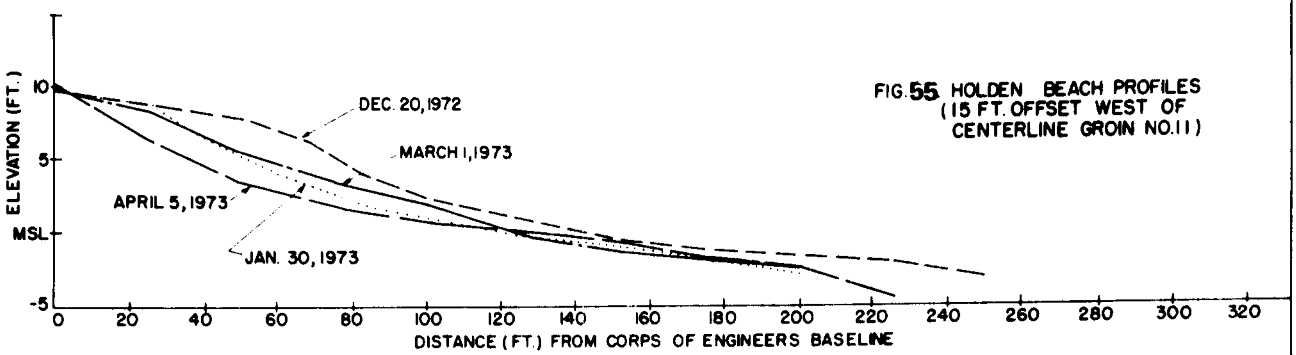


FIG. 55 HOLDEN BEACH PROFILES (15 FT. OFFSET WEST OF CENTERLINE GROIN NO. 11)

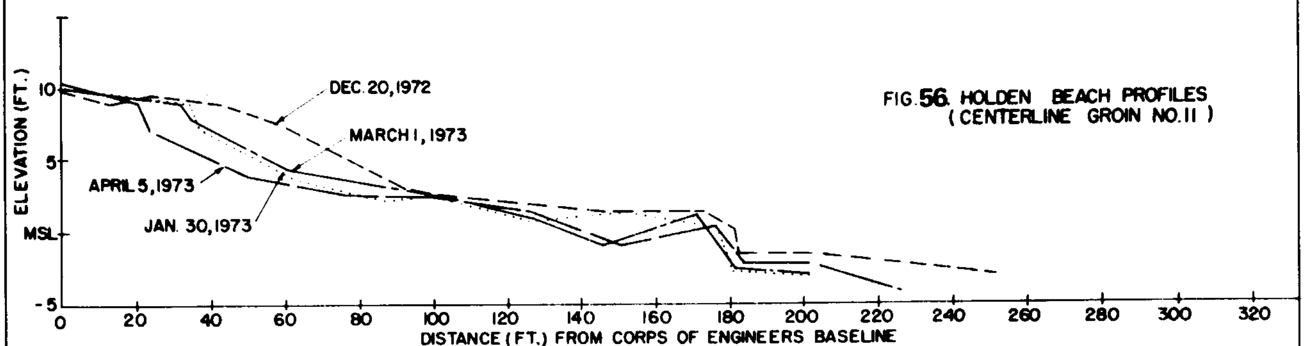


FIG. 56 HOLDEN BEACH PROFILES (CENTERLINE GROIN NO. 11)

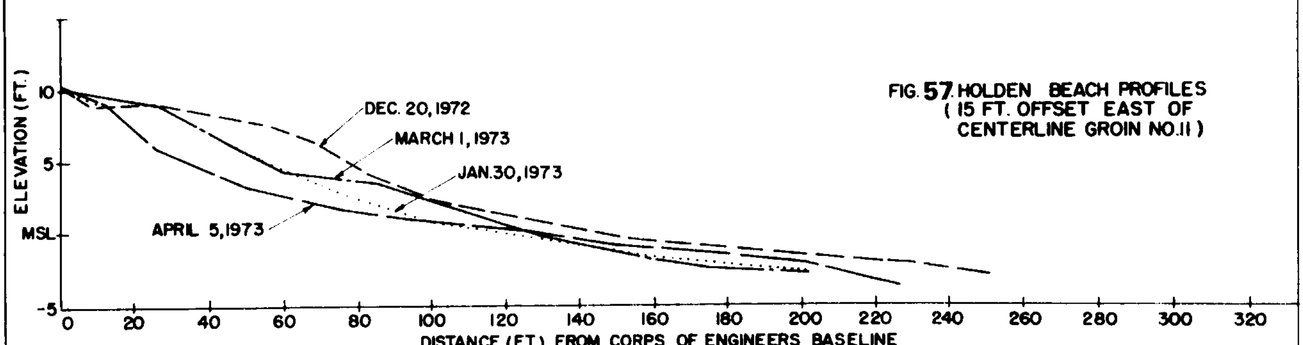


FIG. 57 HOLDEN BEACH PROFILES (15 FT. OFFSET EAST OF CENTERLINE GROIN NO. 11)

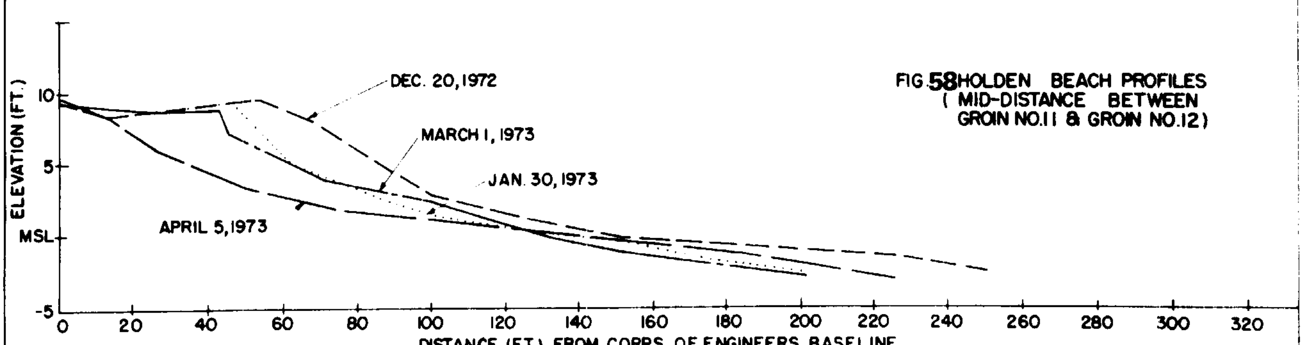


FIG. 58 HOLDEN BEACH PROFILES (MID-DISTANCE BETWEEN GROIN NO. 11 & GROIN NO. 12)

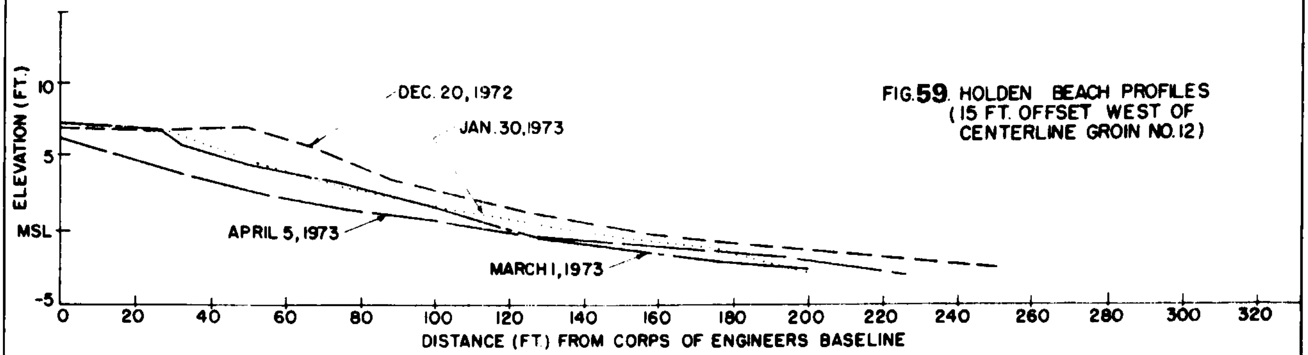


FIG. 59. HOLDEN BEACH PROFILES (15 FT. OFFSET WEST OF CENTERLINE GROIN NO. 12)

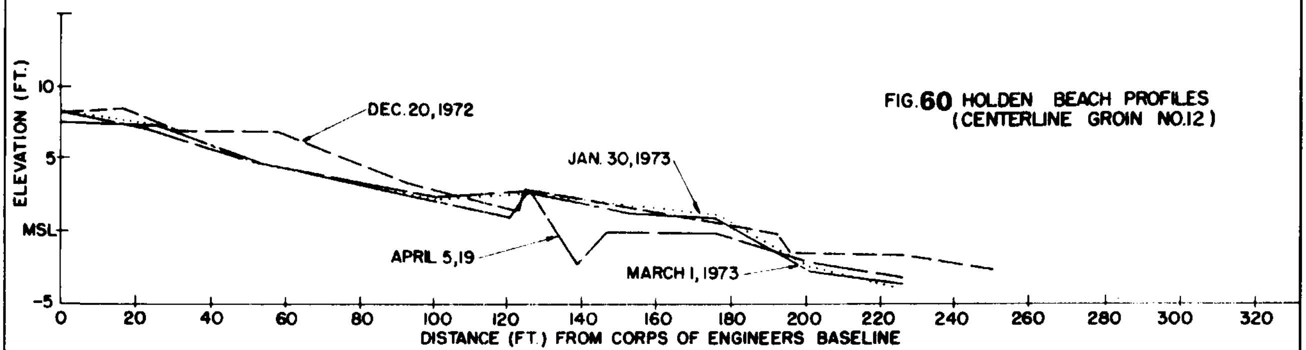


FIG. 60 HOLDEN BEACH PROFILES (CENTERLINE GROIN NO. 12)

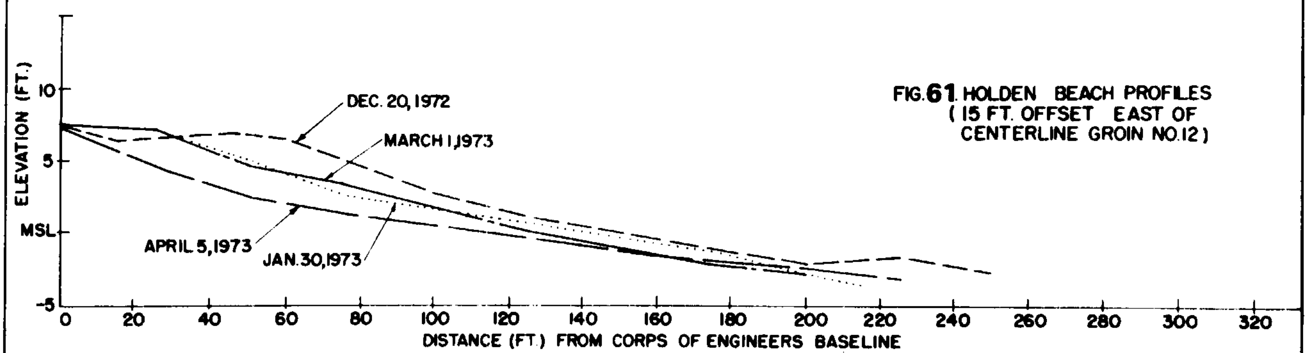


FIG. 61. HOLDEN BEACH PROFILES (15 FT. OFFSET EAST OF CENTERLINE GROIN NO. 12)

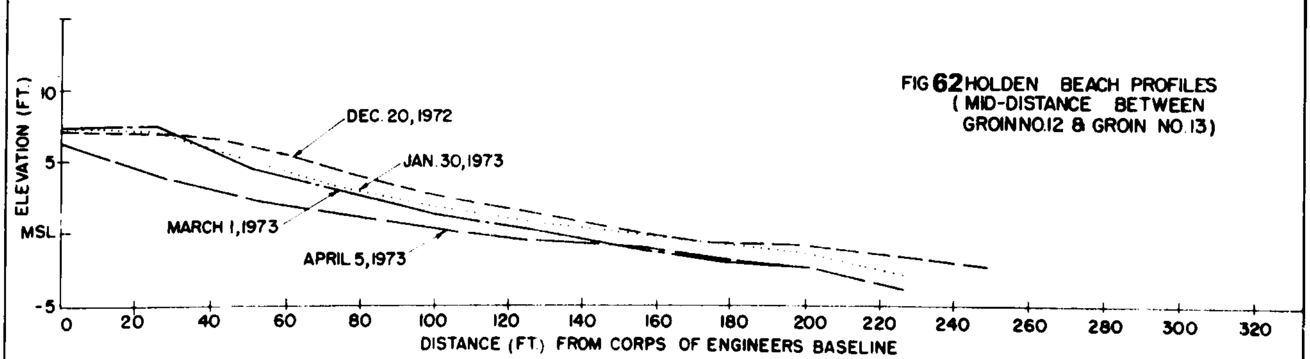


FIG 62 HOLDEN BEACH PROFILES (MID-DISTANCE BETWEEN GROIN NO. 12 & GROIN NO. 13)

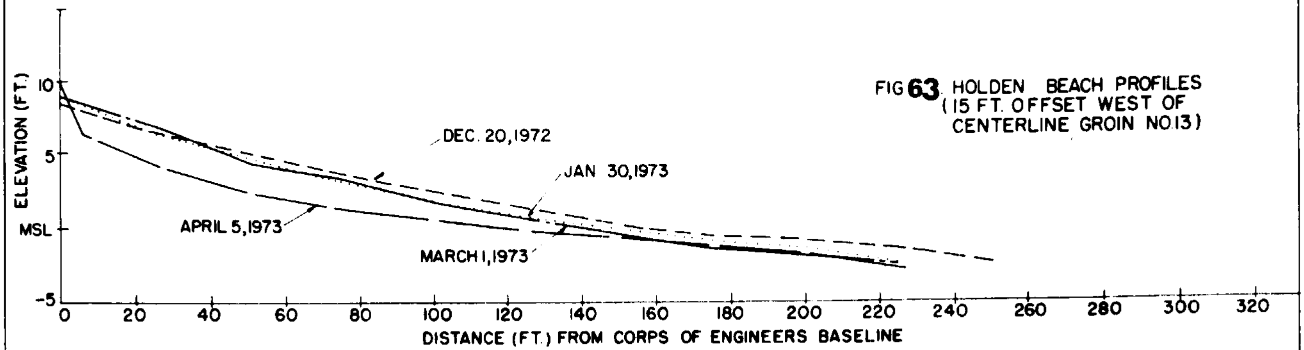


FIG 63. HOLDEN BEACH PROFILES (15 FT. OFFSET WEST OF CENTERLINE GROIN NO.13)

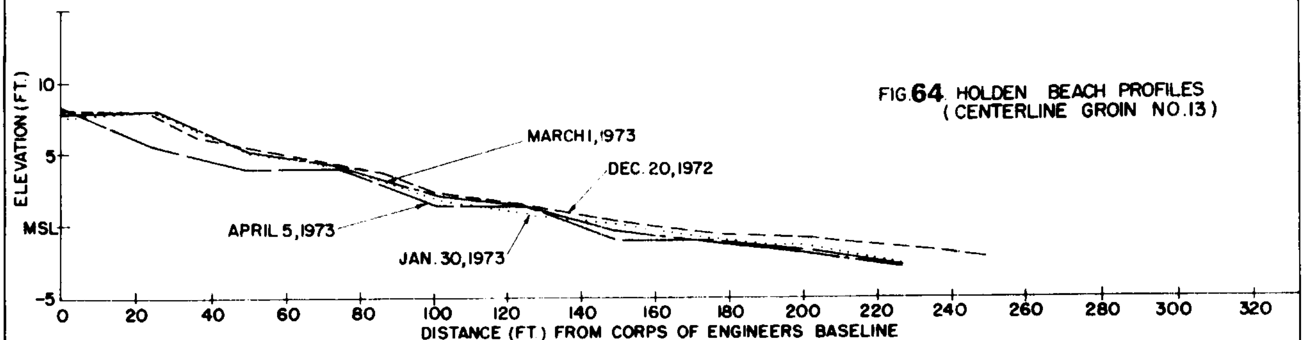


FIG. 64. HOLDEN BEACH PROFILES (CENTERLINE GROIN NO.13)

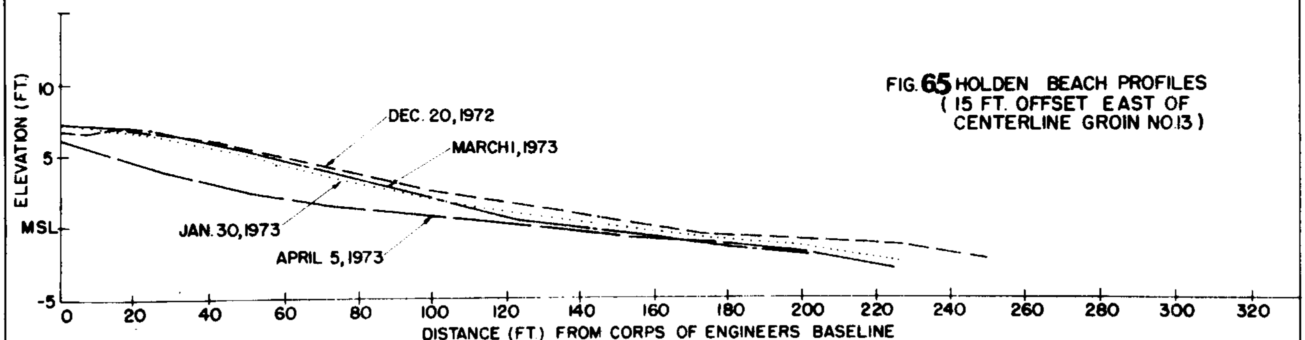


FIG. 65 HOLDEN BEACH PROFILES (15 FT. OFFSET EAST OF CENTERLINE GROIN NO.13)

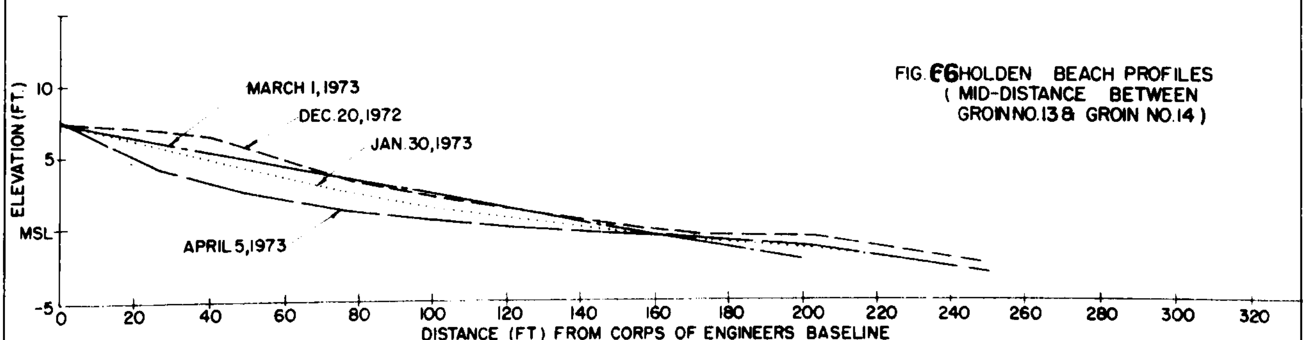


FIG. 66 HOLDEN BEACH PROFILES (MID-DISTANCE BETWEEN GROIN NO.13 & GROIN NO.14)

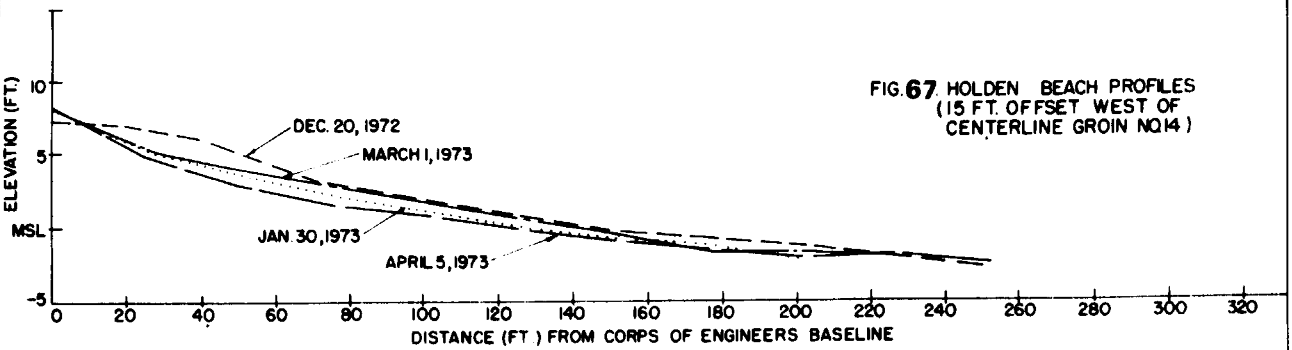


FIG. **67** HOLDEN BEACH PROFILES (15 FT. OFFSET WEST OF CENTERLINE GROIN NO.14)

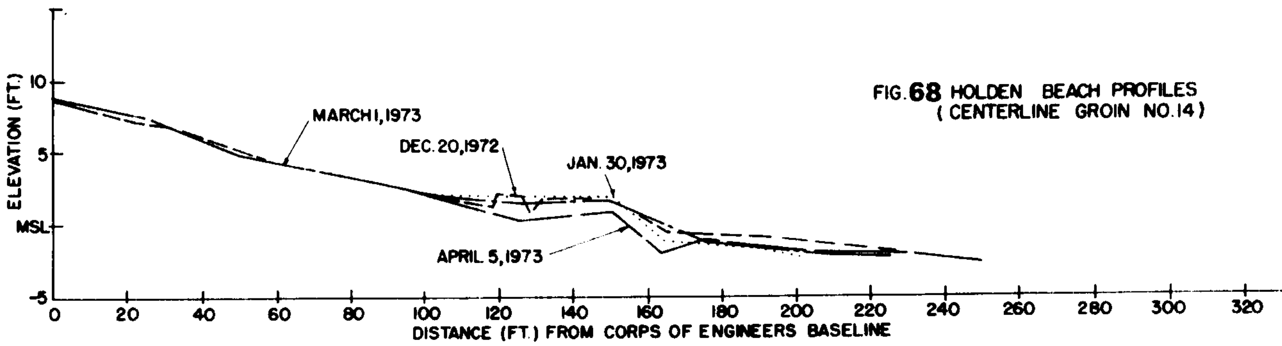


FIG. **68** HOLDEN BEACH PROFILES (CENTERLINE GROIN NO. 14)

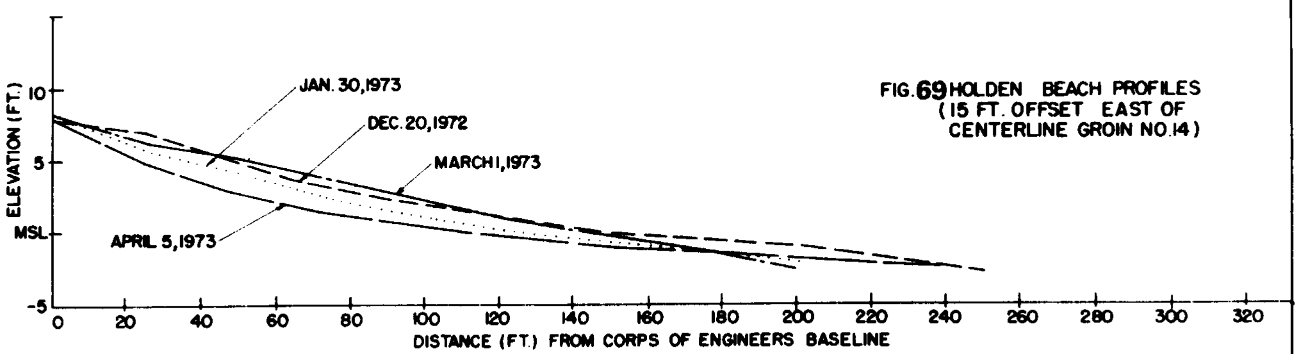


FIG. **69** HOLDEN BEACH PROFILES (15 FT. OFFSET EAST OF CENTERLINE GROIN NO. 14)

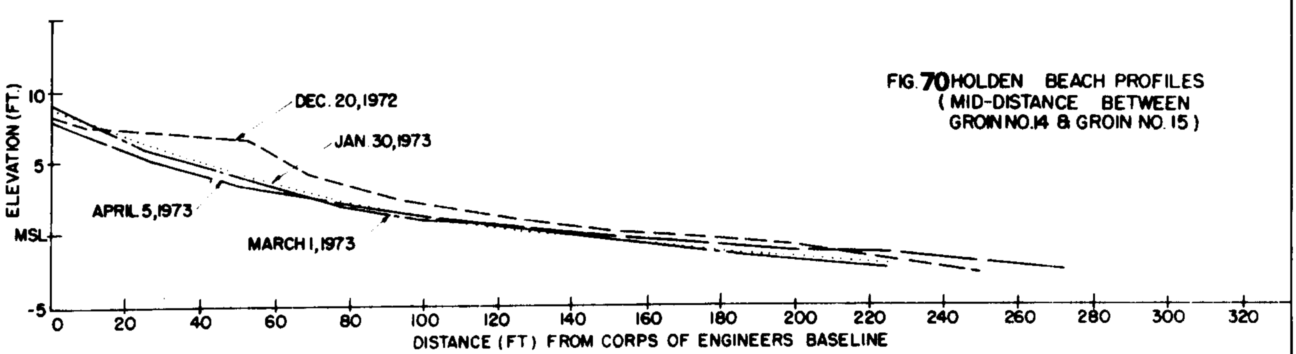


FIG. **70** HOLDEN BEACH PROFILES (MID-DISTANCE BETWEEN GROIN NO.14 & GROIN NO. 15)

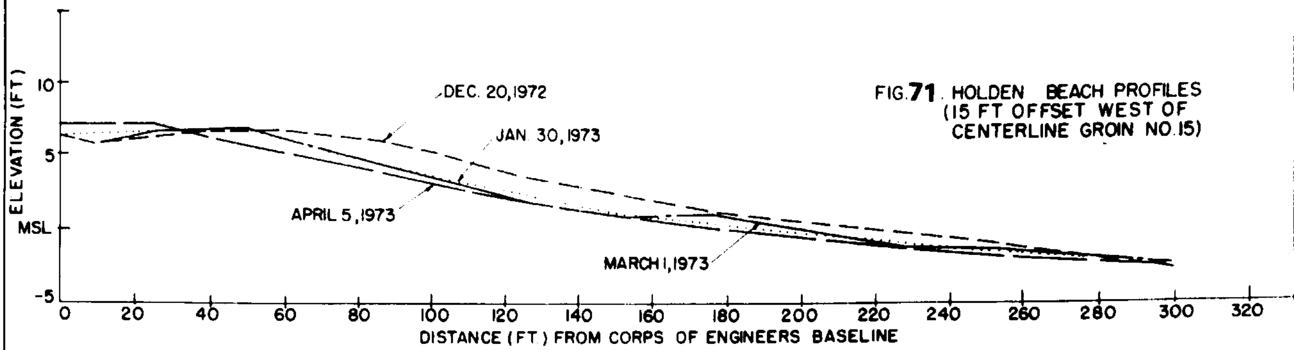


FIG. 71. HOLDEN BEACH PROFILES (15 FT OFFSET WEST OF CENTERLINE GROIN NO. 15)

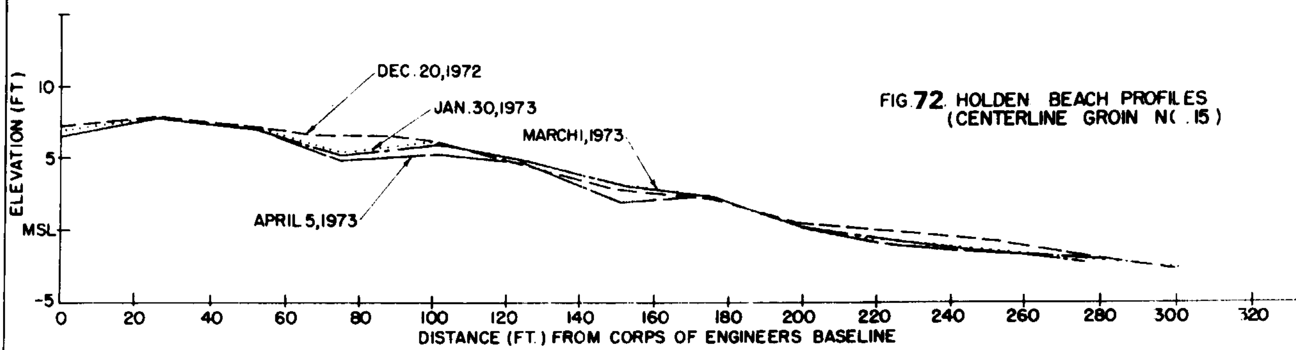


FIG. 72. HOLDEN BEACH PROFILES (CENTERLINE GROIN N(.15)

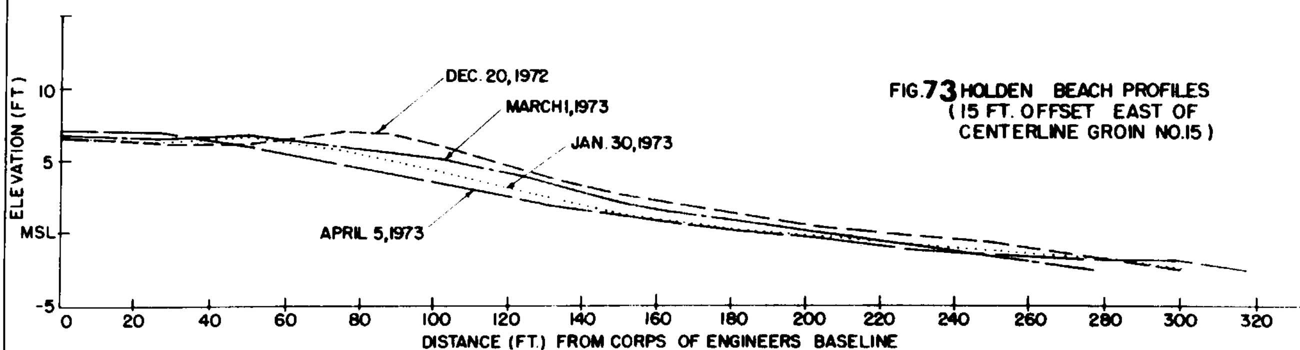


FIG. 73 HOLDEN BEACH PROFILES (15 FT. OFFSET EAST OF CENTERLINE GROIN NO. 15)

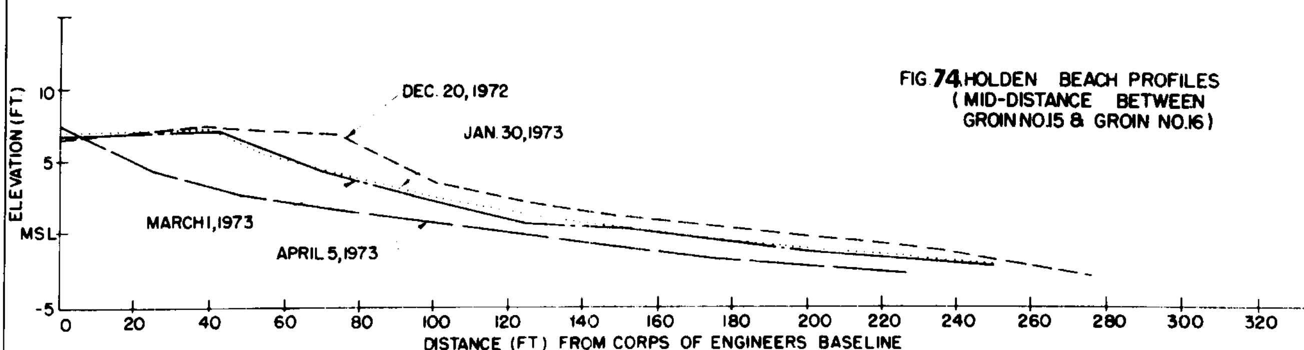


FIG. 74. HOLDEN BEACH PROFILES (MID-DISTANCE BETWEEN GROIN NO. 15 & GROIN NO. 16)

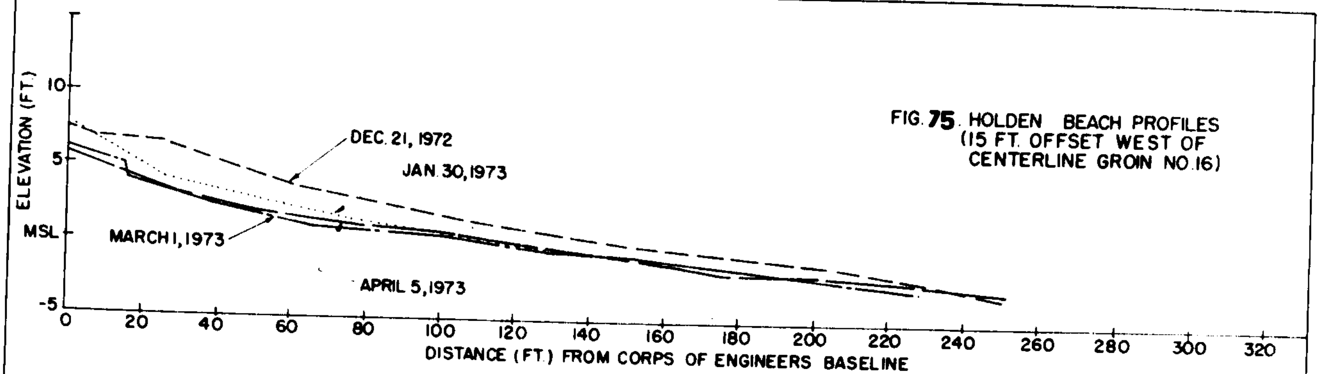


FIG. 75. HOLDEN BEACH PROFILES (15 FT. OFFSET WEST OF CENTERLINE GROIN NO. 16)

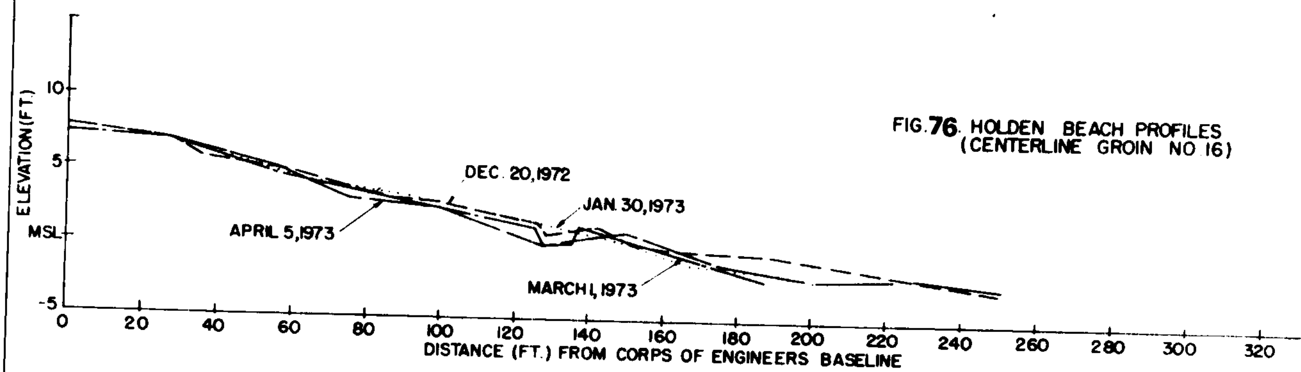


FIG. 76. HOLDEN BEACH PROFILES (CENTERLINE GROIN NO. 16)

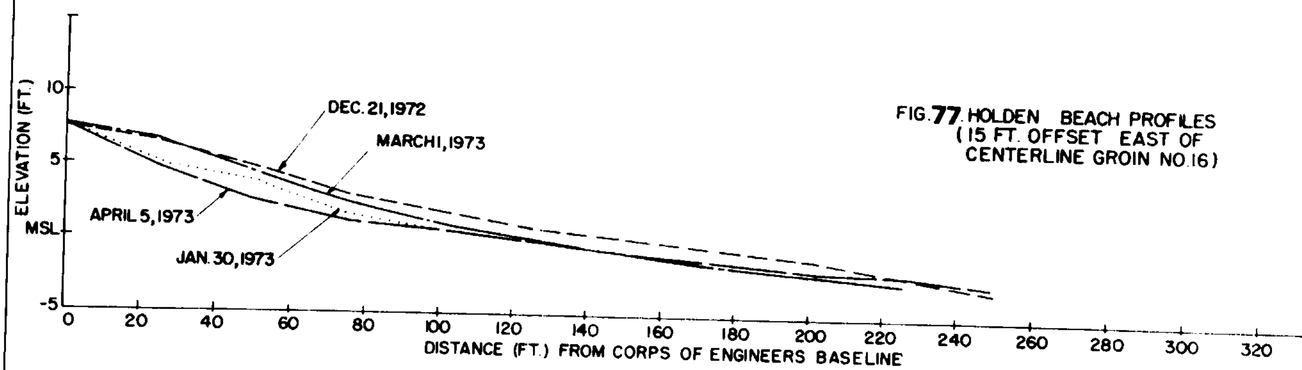


FIG. 77. HOLDEN BEACH PROFILES (15 FT. OFFSET EAST OF CENTERLINE GROIN NO. 16)

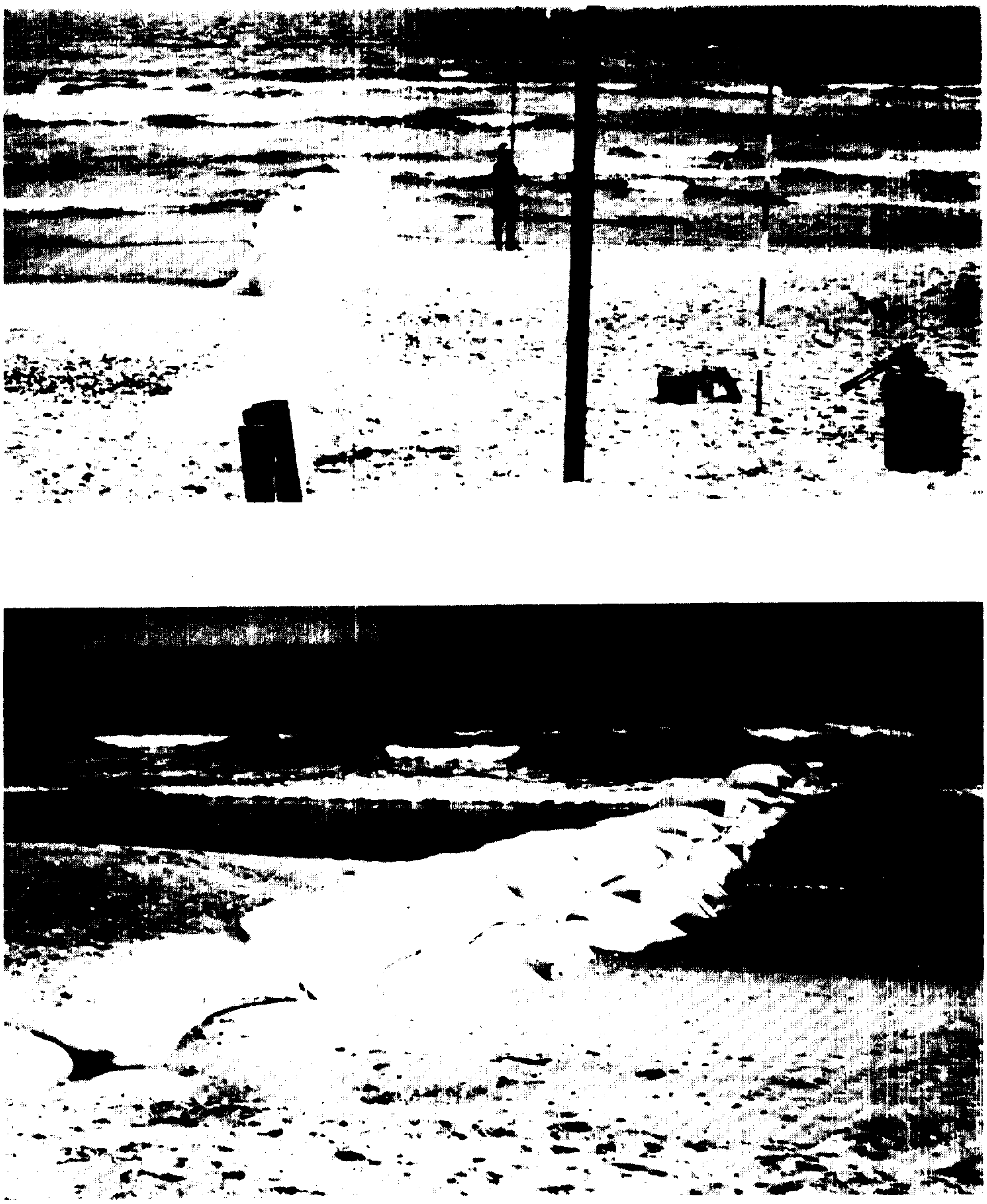


FIGURE 78. NYLON BAG GROINS ON HOLDEN BEACH
BRUNSWICK COUNTY, NORTH CAROLINA.

in stabilizing the dredged material.

DURABILITY OF BAGS

Experience has shown that the fibrous nylon bags are easily destroyed by sharp articles. Several precautions were taken to prevent broken shells or similar sharp fragments from entering the bags during filling operations. Beach vandals (whether for malicious purpose or unintentional accident) destroyed several bags in the groin field. An ordinance was enacted by Holden Beach authorities thus providing a punitive penalty for tampering with the structures.

COST COMPARISON

The groins of Holden Beach cost $13.50 per linear foot. This cost compares favorably to $18.89 per linear foot for a sand-filled nylon bag project at Singer Island, Florida (6). A timber groin field was estimated at $125 per linear foot of structure while a concrete groin field was estimated at $200 per linear foot. Assuming the life of the sand-filled bag groins to be two years, the timber groins to be five years and the concrete groin to be ten years, the cost per year of useful economic life for the sand-bag groin compares very favorably with the other types of groins.

CONCLUSION

Nylon bags can be used to construct inexpensive groins to stabilize a beach strand. With an economic life of two years, the bags compare favorably with other types of construction material. The capital outlay for a nylon bag structure is nominal, thus avoiding a large financial burden on a beach community.

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VESSEL TRAFFIC SYSTEM
HOUSTON-GALVESTON

by

Commander T. C. Volkle*

ABSTRACT

An increasing awareness of actual and potential dangers to our environment has occurred in recent years. Marine transportation, the least expensive way to move bulk materials, has its share of such potential dangers. In part, this is because of worldwide demand for huge quantity deliveries in the shortest possible time. This demand conceived the "Super Ship" of today's fleet which taxes the safety limits of most of the world's ports. Consequently, there are two major considerations for ports and waterways. One is to decrease turnaround time. The other is to reduce the likelihood of marine accidents, thereby protecting our shores from hazardous spills.

One device which has been adapted to promote safety and economical movement of marine traffic is the Vessel Traffic System (VTS). This is relatively new to the U.S. but not the rest of the world. The first VTS was installed in Liverpool in 1948. Germany, The Netherlands, Canada, Japan and many other countries have followed suit and have experienced very favorable results in reducing collisions and groundings.

The Coast Guard's present involvement in VTS's began in early 1969 when a project established an experimental harbor advisory radar system in San Francisco, that became an operational system in the summer of 1972. The collision between two tankers in San Francisco Bay in January 1971 accelerated plans for development of other operational systems. Today there are systems in San Francisco, Puget Sound, and the Galveston Bay area. Other systems are in various planning stages.

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*Commanding Officer, Houston-Galveston Vessel Traffic System
U.S. Coast Guard

Houston-Galveston VTS

Few other waterways in the world can compare with the Houston-Galveston area in its potential for danger on a mile by mile basis. Over 10% of the U.S. petroleum refining capacity and 20% of our petrochemical capacity are located here, with a capital investment of over 5 billion dollars. Of the cargo shipped here (some 117 million short tons plus 20 million tons passing through on the Gulf Intracoastal Waterway in 1973), 70% falls into the category of "dangerous". The risks present in this area indicate that a vessel casualty could be catastrophic to both population and industry.

Present VTS operations consist of gathering information about vessel transits, channel conditions, aid to navigation discrepancies and weather, and then passing that information back to the navigator to help him best plan his own trip. Under no circumstances will the VTS attempt to navigate vessels from shoreside.

To accomplish this, we have a sophisticated communications system with remote sites and the capability of covering small or large areas. We have low light level, closed-circuit televisions along the upper Houston Ship Channel to provide twenty-four-hour surveillance of the twisting parts of the waterway. We have "hotline" telephone communications with other operational units in both Galveston and Houston and we have a manual tracking board, where we keep tabs on all marine traffic and events which can affect that traffic.

Ours is a voluntary system. In the first six months of operation, VTS logged more than 6,500 large vessels and 32,000 tows transiting the system. With over 99 percent participation, acceptance by the marine industry seems to be nothing short of phenomenal.

The immediate future of the Houston-Galveston VTS includes a computerized tracking system to replace the presently used tracking board, radar coverage of Galveston Bay and the seaside entrance, and finally a mandatory VTS.

VTS meets the need for a reasonable and cost-effective means of reducing the probability of a major catastrophe in the Houston-Galveston area, thus fulfilling the requirements of The Ports and Waterways Safety Act of 1972.

A chart of the Vessel Traffic System Area between the turning basin and the Upper Galveston Bay is shown in Figure 1. The shaded areas indicate precautionary areas and stars indicate reporting points.

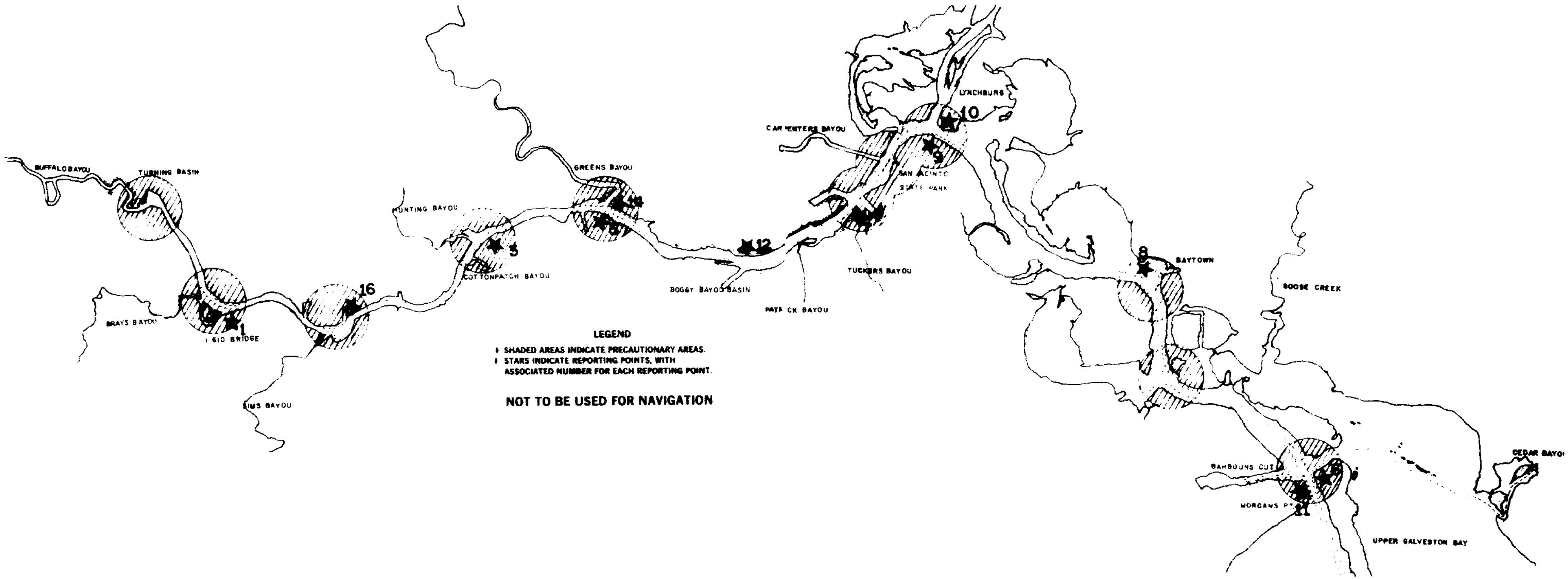

Figure 1. Vessel Traffic System Area.

THE NATIONAL DREDGING STUDY

by

W. R. Murden*

ABSTRACT

At the direction of the Congress the Corps of Engineers, U.S. Army, has compiled a comprehensive study of the national dredging requirements. This paper will include a summary of the findings and conclusions of this study.

The study considers the type, condition and number of dredges operated by the industry and the Corps of Engineers and a forecast of the type and number of industry and Corps of Engineer dredges required over the next ten-year period.

The study addresses three major subjects in the dredge field; past performance, future requirements and procedures, and an evaluation of Corps of Engineers bidding practices and procedures.

The study includes an assessment of the utilization and cost of operating industry and Corps dredges; a summary of the structure and composition of the dredging industry.

The study also includes a discussion of the future effects of environmental regulations on dredging operations and costs, the outlook for dredging in deepwater ports, a forecast of the national dredging requirements, and a discussion of future dredging technology.

The paper will also include a summary of the legislative background relating to Corps of Engineers dredging activities and a discussion of estimating procedures.

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*Directorate of Civil Works
Office of the Chief of Engineers
U.S. Army Engineers

INTRODUCTION

During the period following 1965, the annual Corps of Engineers budget for new work, or waterway and harbor improvement projects, was reduced significantly and has remained at a reduced level. The drastic reduction in the funding program, which occurred over an extended interval, and the cumulative effects of inflation during the period 1965-1973, have resulted in a substantial decrease in the utilization of contractor-owned plant and a controversy over the utilization rate and the need for Corps of Engineers dredges.

As a result of this controversy, the congressional committees on appropriations, in conjunction with their review of the FY 1973 budget, placed a moratorium on the replacement or modification of Corps of Engineers dredges pending the completion of a comprehensive study of the national dredging requirements. The Committees on Appropriations also directed that the findings and recommendations contained in General Accounting Office (GAO) Report No. B-161330 be considered in the preparation of the study. The GAO report outlined three basic alternatives for the Corps to accomplish its dredging workload:

a. Maintaining the present level of effort with existing Corps plant.

b. Taking over a larger share of the program by expanding the Corps plant capability.

c. Curtailing or eliminating the Corps plant capability.

The need for conducting a detailed and comprehensive study with complete objectivity was evident. Consequently, the Chief of Engineers engaged the prominent management-engineering firm of Arthur D. Little, Incorporated (ADL), to make an in-depth study of dredging practices over the period of 1974-1983; an evaluation of dredging requirements for 1974-1983; and an evaluation of the Corps of Engineers procedures connected with bidding and estimating dredging projects. In addition, the Chief of Engineers established an advisory committee, composed of representatives from the dredging industry, port authorities and retired Corps personnel to develop the scope of the study, and to prepare a report summarizing the views of the advisory committee on the findings and conclusions contained in the study prepared by the ADL firm.

Arthur D. Little (ADL) began the study in September 1973 and completed it in August 1974. The study report consists of eleven volumes and is divided into three parts which are outlined below:

a. Part I - A detailed review and analysis of the Federal dredging program during 1964-1973; including the utilization of Corps equipment and industry equipment and the division of the annual workload between industry and the Corps.

b. Part II - A detailed forecast of the national dredging requirements, both the Corps dredging program and private work, for 1974-1983; considering the impact of changed requirements, the methods and equipment that might be used, and the various alternatives of sub-dividing the dredging workload of the Corps.

c. Part III - A detailed review and analysis of the Corps bidding and estimating procedures, and an analysis of the effect of the Corps policies and procedures on the dredging operations.

Taken together with the supplemental report to the Chief of Engineers prepared by the Advisory Committee, the study is the most comprehensive report on the national dredging program ever assembled. The presentation that follows summarizes the principal finding and conclusions of the study.

2. PART I - PAST PERFORMANCE (1964-1973)

Based on information furnished by the Corps of Engineers, the dredging industry, and commercial information sources, ADL developed data on the comparative utilization and costs of operating Corps and industry plant, and the division of federal expenditures between Corps and contractor plant during the reference period.

a. Dredging Activity with Corps Plant.

Let us first examine the hired labor operations of the Corps. Although there were a few changes in the size and composition of the Corps dredging fleet between 1964 and 1973, a representative tabulation, indicating the number and types of dredges available in 1973 is shown on Figure 1. This figure indicates

FIGURE 1

COMPOSITION OF CORPS OF ENGINEERS DREDGING FLEET IN 1973

TYPE	UNITS OPERATING	UNITS NOT OPERATING	TOTAL	PERCENT
HOPPER	16*	-	16*	32.7
CUTTERHEAD	12	3	15	30.6
DUSTPAN	6	2	8	16.3
SIDECASTING	3	-	3	6.1
DIPPER	2	-	2	4.1
BUCKET	4	1	5	10.2
	43	6	49	100.0

* REDUCED TO 15 IN MAY 1974 BY THE LOSS BY COLLISION AND SINKING OF THE DREDGE MACKENZIE.

that three types of dredges; hopper, dustpan, and cutterhead make up 80% of the Corps fleet, with the hopper dredge being the predominant type, accounting for about 33% of the total.

Figure 2 illustrates the utilization of these dredges. As indicated in this figure, the total number of effective dredging hours of all the Corps dredges averaged about 220,000 hours annually, with little change from year to year. Also, it shows that hopper dredges and cutterhead dredges have consistently accounted for about 70% of the total effective hours of all the Corps dredges. The only significant trends observed were a decline of about one-third in the hours worked by dustpan dredges, and a compensating increase in the utilization of sidecasting dredges.

Corps dredges are used primarily on maintenance dredging projects, about 90% of the time, rather than on new work dredging as illustrated in Figure 3. This figure also indicates that during the period of 1964-1973, as the new work utilization declined, the total effective hours of the Corps plant applied to maintenance dredging increased. This trend was reflected in the utilization of all types of dredges and resulted in a complete absence of use on new work of the Corps cutterhead, dustpan and bucket dredges after 1970.

Although subject to some fluctuation from year to year, the annual volumes dredged by Corps plant in navigational maintenance work did not vary significantly from the average annual volume

FIGURE 2

UTILIZATION OF CORPS OF ENGINEERS DREDGES

BY TYPE OF DREDGE

1964 - 1973

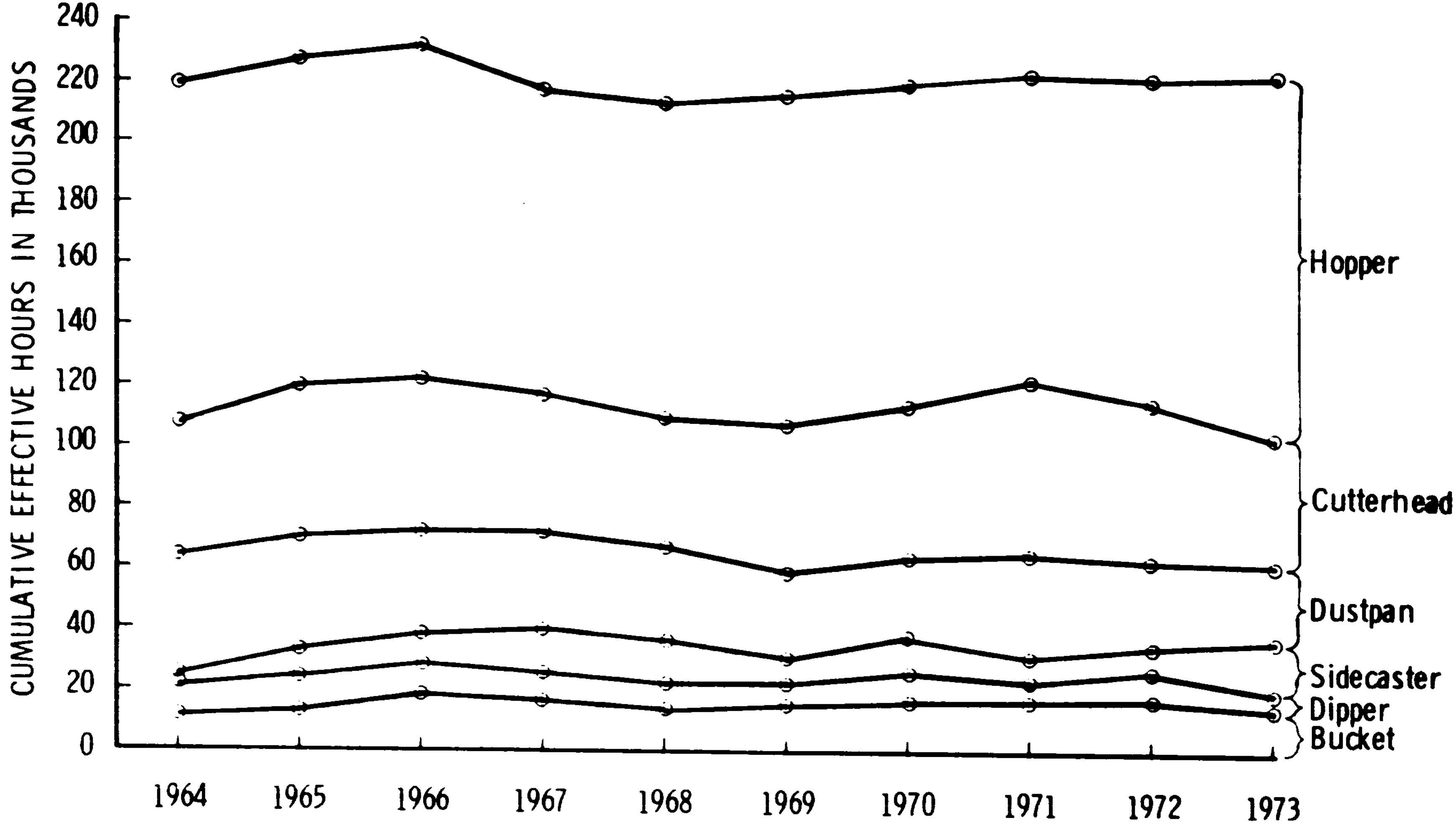
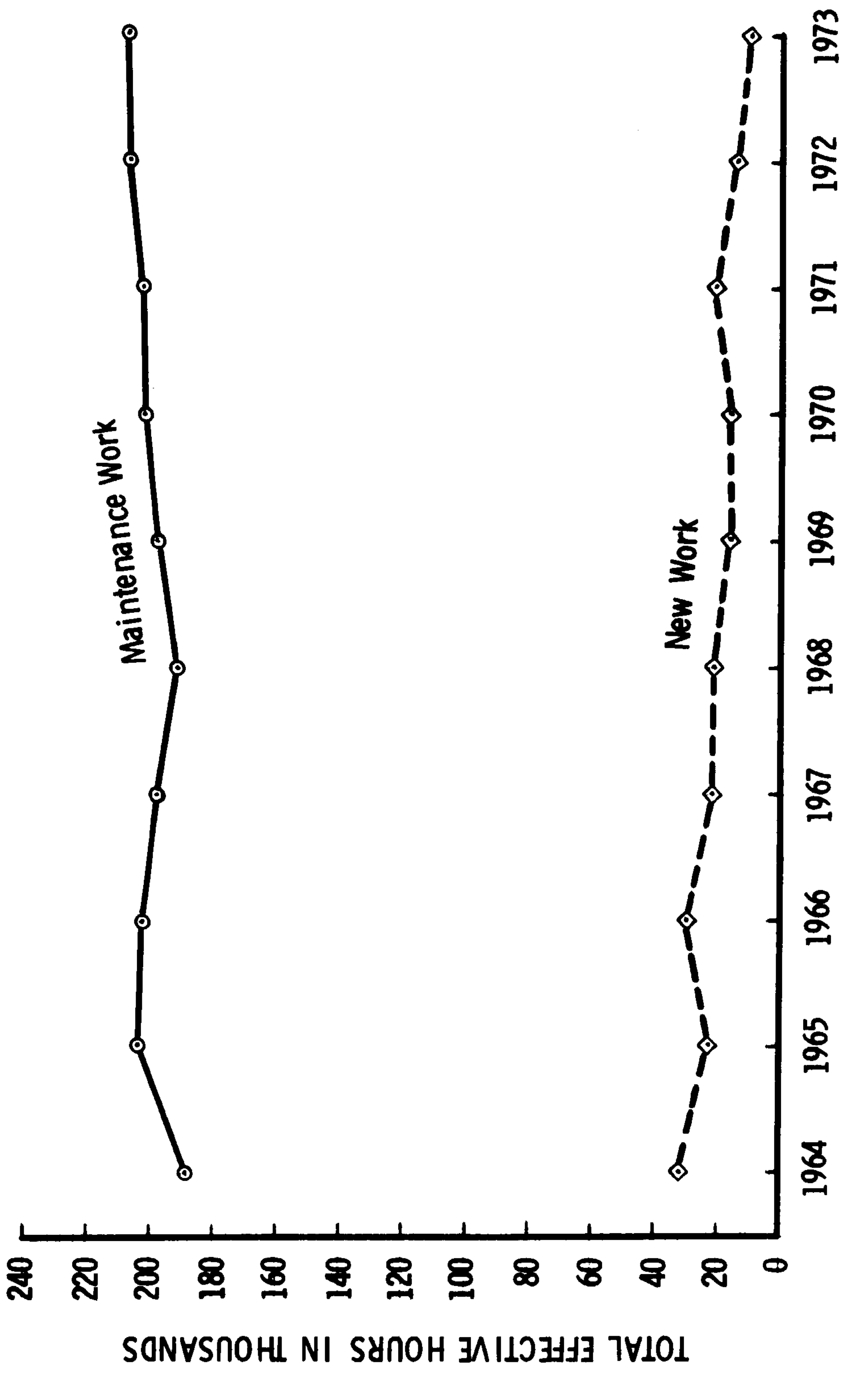


FIGURE 3

UTILIZATION OF CORPS OF ENGINEERS DREDGES

BY TYPE OF WORK

1964 - 1973



of 137 million cubic yards. However, in the case of new work, the annual volumes excavated with Corps plant, fell significantly from 16 million cubic yards in 1964 to less than 6 million in 1973. The study also indicates that the volume of maintenance work accomplished with Corps dredges in the Gulf Coast region more than tripled between 1964 and 1973, while it decreased substantially in the West Coast and interior waterways regions, and remained relatively constant in the East Coast region. Figure 4 shows the nation-wide volumes of material removed by the three predominant types of Corps dredges, the hoppers, the dustpans and the cutterheads. It can be seen that in 1964 hopper dredges excavated nearly 60 million cubic yards and dustpan dredges about 55 million cubic yards. On the other hand, in 1973, hopper dredges removed over 72 million cubic yards, a 20% increase over the 1964 level; while dustpans removed only 37 million, a 33% decrease from 1964. The cutterhead annual volume held fairly steady between 22 and 27 million cubic yards, up to 1973, when the volume dropped sharply to 16 million cubic yards.

From a cost standpoint, the dominant role of the hopper dredges in the plant program of the Corps is even more pronounced as illustrated in Figure 5. In overall terms, in 1973, the cost of hopper dredges amounted to 38.8 million, and accounted for 57% of the total Corps plant operating costs.

In general, the Corps of Engineers has strived to maintain a high level of utilization of its plant, particularly the

FIGURE 4

NATION-WIDE DREDGING VOLUME BY CORPS OF ENGINEERS

HOPPER, DUSTPAN, & CUTTERHEAD DREDGES

1964 - 1973

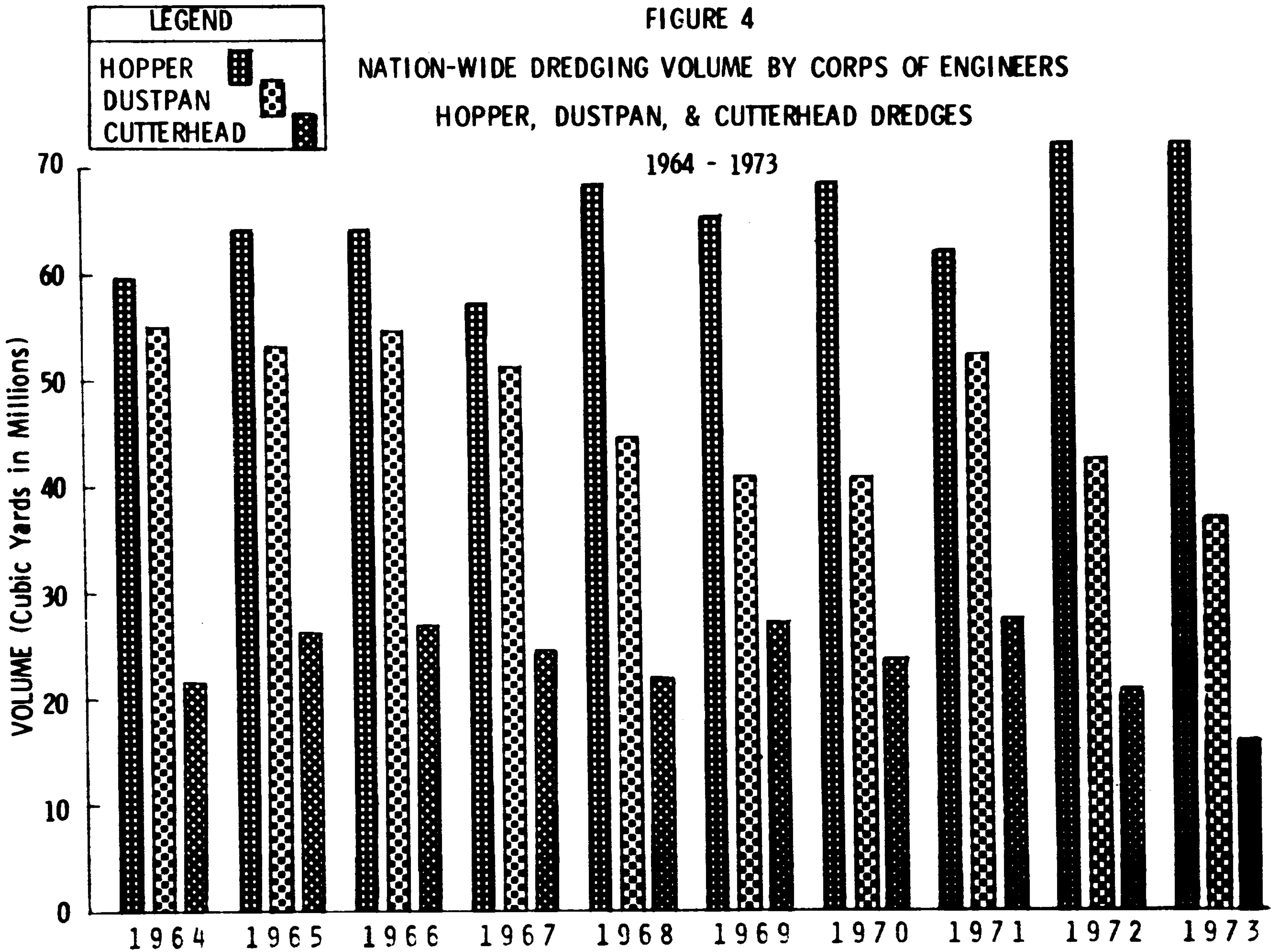
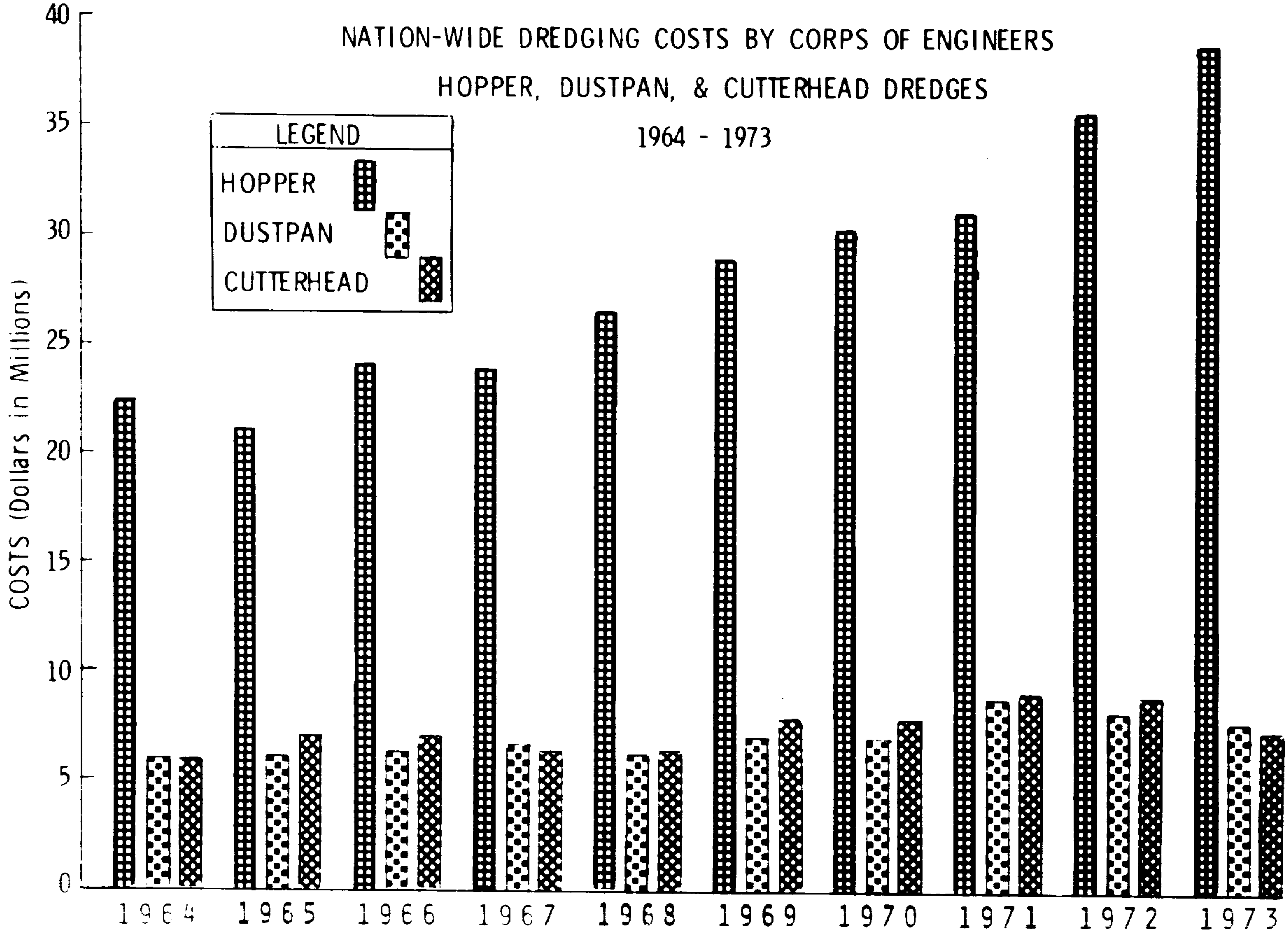


FIGURE 5

NATION-WIDE DREDGING COSTS BY CORPS OF ENGINEERS

HOPPER, DUSTPAN, & CUTTERHEAD DREDGES

1964 - 1973



hopper dredges, due to the relatively high capital investment and related costs involved in the operation of this type equipment. The ADL report indicates that this objective is not considered to be in conflict with the laws and policies under which the Corps conducts its dredging program. Notwithstanding the effort to maintain a high utilization rate for Corps dredges, it is the general policy of the Corps of Engineers to perform all work by contract whenever the nature of the work and its time for execution will permit, provided reasonable bids can be obtained, and unless it is clearly evident that it would be in the best interests of the Government to have the work performed by Government plant and hired labor.

b. Division of Federal Dredging Activity.

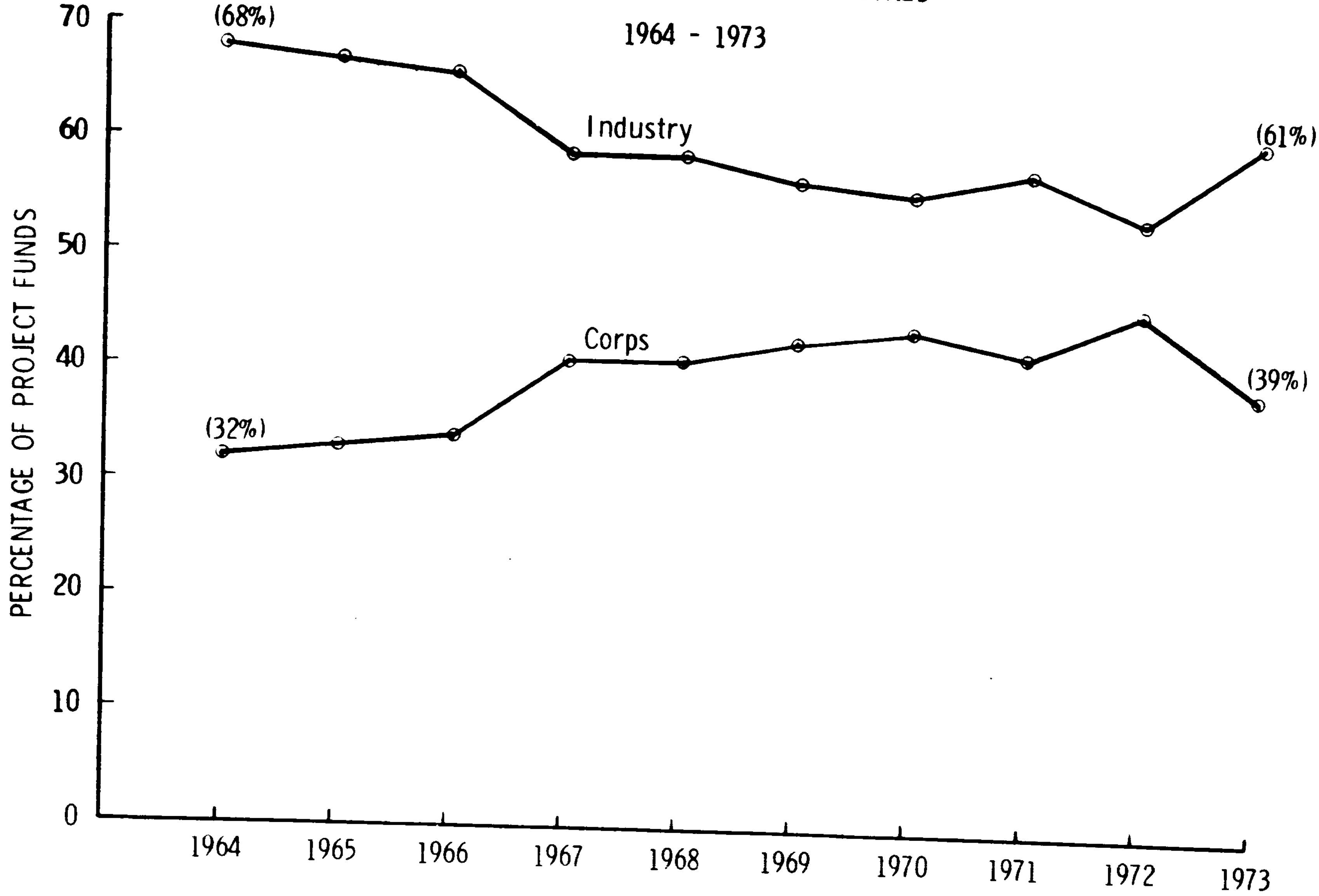
ADL developed data on the distribution of expenditures for dredging between the Corps and industry for the period of 1964-1973. Figure 6 shows the annual percentages of overall project funding for maintenance and new work combined. As indicated, the Corps/industry distribution of funds in 1964 was 32%-68%, respectively, while in 1973 the percentages were 39%-61%, indicating a 7% decrease in the industry's share of work. In further analyzing this trend, it was found that while the Corps and industry annual maintenance funding remained at about the same levels over the ten-year period, the total new work funding program decreased markedly. Although the Corps/industry distribution of new work

FIGURE 6

DIVISION OF TOTAL EXPENDITURES

MAINTENANCE & NEW WORK COMBINED

1964 - 1973



funds continued at about the same ratio, the major impact of the decline was absorbed by the industry, which generally accomplishes the most, 85% to 90%, of the new work requirements.

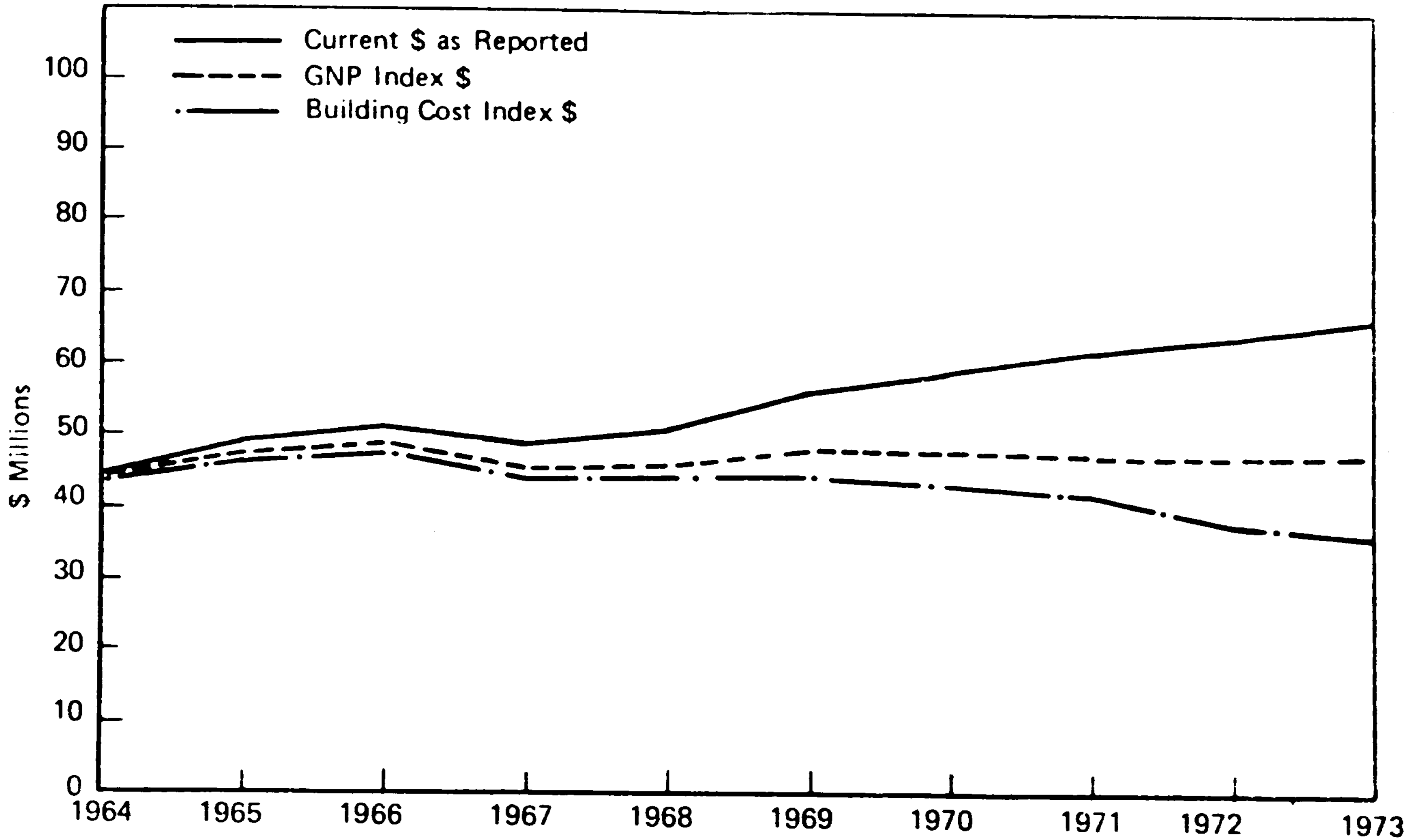
In order to better illustrate the impact of the decline in workload, ADL presented dredging project expenditures in both current and constant dollars with the latter shown in two ways:

(1) In constant 1964 dollars adjusted with the Gross National Product, GNP, deflator.

(2) In constant, 1964 dollars adjusted with the Engineering News Record (ENR), Construction Cost Index based on construction material costs and skilled labor rates.

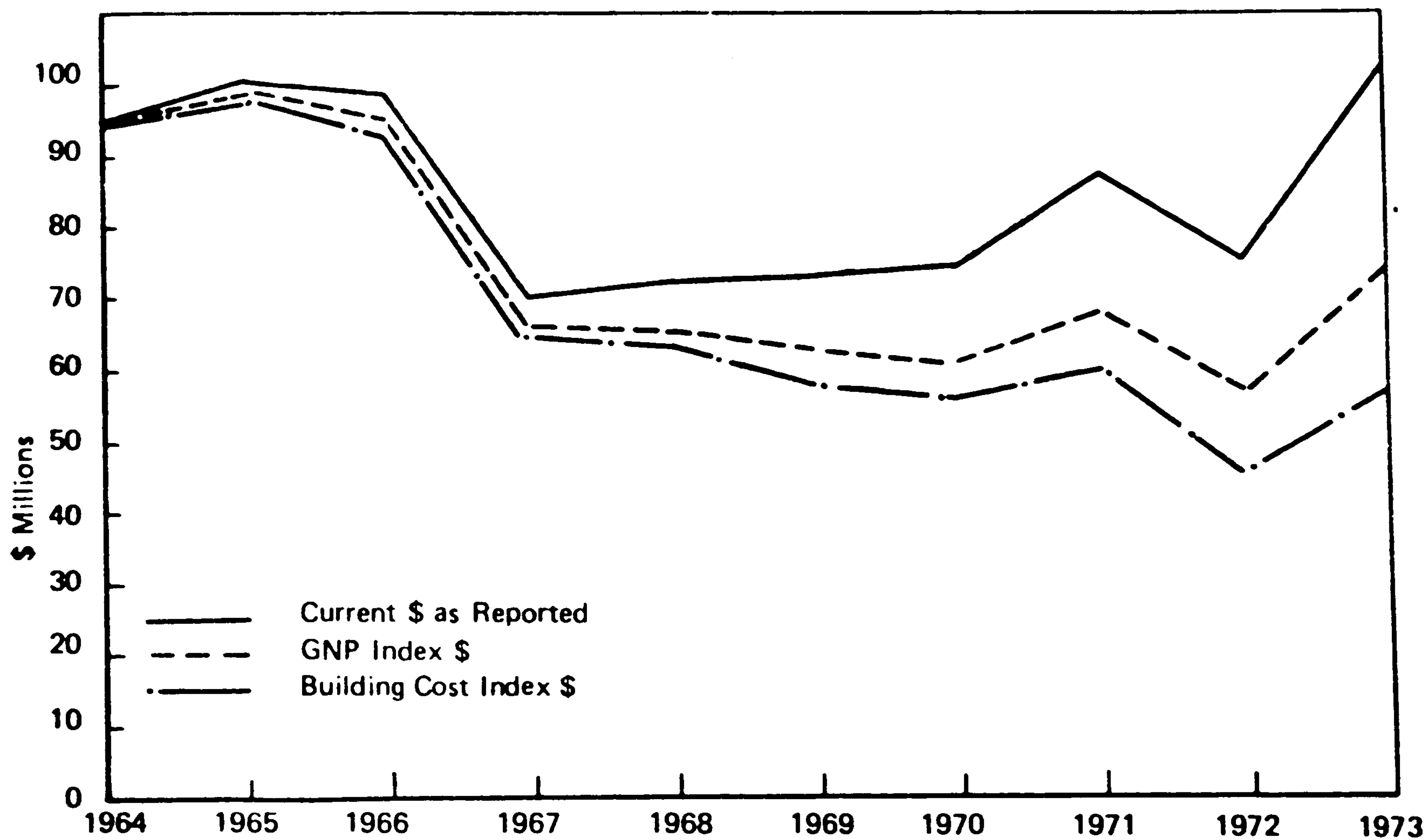
Figure 7 shows the effect of these factors on the Corps plant activities. This figure indicates that while Corps plant expenditures, in current dollars, increased from $44.1 million in 1964 to $66 million in 1973, in effect, the level of expenditures in terms of constant dollars decreased about 18% when related to the ENR Building Cost Index. Figure 8 shows similar data applicable to Federal dredging accomplished by the industry. This figure indicates a marked decline in expenditures on a current dollar basis for most of the ten-year period, which is attributed mainly to a substantial decrease in the New Work dredging program. In terms of constant dollars, using the ENR factor, the 1973 industry expenditure level was $56.1 million, a 40% reduction below the 1964 current dollar amount of $94.2

FIGURE 7



FEDERAL EXPENDITURES ON CORPS DREDGING ACTIVITY

FIGURE 8



FEDERAL EXPENDITURES ON INDUSTRY DREDGING ACTIVITY million. From an overall viewpoint, the Corps and industry current dollar expenditure level of $138.3 million in 1964 decreased to $92.4 in 1973, a reduction of 33%, when related to the ENR Building Cost Index data.

While the funding limitations have resulted in a major adverse impact on the dredging program there can be little doubt that environmental restrictions and considerations have also contributed to the financial dilemma which the dredging industry has faced for the past several years.

c. Structure and Composition of the Dredging Industry.

Based on analyses of Corps of Engineers bid data, Dun and Bradstreet reports, and meetings with dredging industry representatives, ADL developed an industry profile based primarily on 1972 information, a year with a comparatively full range of available data.

While a total of almost 200 individual companies were identified as having been engaged in the dredging industry at various times during the period 1964-1972, only 87 were found to be active in 1972.

The overall gross revenues during 1972 for the 87 companies composing the dredging industry were estimated at approximately $230 million. However, authoritative figures were available from only 28, or about one-third, of these companies, which accounted for $124.3 million, or 54% of the estimated revenues for the entire industry. On the basis of the 1972 data, a distribution based on a range of revenues for the 87 active companies is shown in Figure 9. It will be noted in this figure that a major portion, over 55% of the dredging industry reveneus, was earned by nine companies or about 10% of the industry. It is also considered noteworthy that only two of these nine companies had revenues in excess of $20 million. With the annual revenues of the remaining 78 firms falling below the $5 million mark, it is clear that most of the industry operates at a level that places them in the category of "Small Business" under the Small Business Administration regulations.

Approximately 45% of the industry revenues in 1972 were derived from Corps work and 55% came from work done for other customers. While this relationship can be expected to vary somewhat from year to year, it was concluded that the Corps has been the largest dredging customer in the past, and probably would continue to be so in the future.

The study indicates that the dredging industry is highly fragmented, and has been undergoing a process of contraction and consolidation for several years. The trend toward a decline in the size of the industry has evidently resulted from the high capital cost of replacing equipment, the impact of inflation on operating and repair costs, and the restraints on dredging activities resulting from environmental restructions and considerations.

FIGURE 9

ESTIMATED COMPOSITION OF DREDGING INDUSTRY IN 1972

SIZE	REVENUE RANGE	NO. OF FIRMS	ESTIMATED DREDGING REVENUES 1972	
			$ MILLIONS	% INDUSTRY TOTAL
SMALL	UNDER $1 MILLION	36	12.5	5.4
MEDIUM	$1 - 5 MILLION	42	89.3	38.9
LARGE	OVER $5 MILLION	9	128.2	55.7
	TOTALS	87	230	100.0

d. Industry Utilization and Cost Experience.

ADL experienced some difficulty in obtaining detailed information on equipment utilization and costs within the dredging industry over the period of 1964-1973. Thus, the industry survey was limited to the period of 1970-1973, which included the broadest range of data, in an effort to provide the most representative analysis. Based on the information available during this period, the utilization of a selected segment of the industry dredges is summarized in Figure 10. Although hydraulic dredges are the most heavily utilized of all the commercial dredges, the depressed condition of the industry is indicated in the fact that the utilization of these dredges has been substantially less than 50% in recent years. Figure 10 also indicates that Corps of Engineers work constituted the most stable proportion of use for this type dredge - consistently near 50% of the time worked.

Wide variations occurred in the municipal, industrial and foreign markets during the reference period as indicated in Figure 11, which summarizes the utilization of hydraulic and clamshell dredges by customer classification.

Dredging for navigational purposes was the predominant form of work undertaken by the companies that furnished data, with maintenance work accounting for about 45% of the overall total utilization.

The response of the dredging industry to requests for cost data was extremely limited with only three companies furnishing

FIGURE 10

Summary of Industry National Utilization
by
Type of Dredge and Customer

	Corps of Engineers	Ports and Munic.	Private Industry	Foreign	Total Utilization
55 HYDRAULIC DREDGES					
1970	22.1%	6.4%	14.7%	1.3%	44.5%
1971	23.4	5.7	7.2	0.2	36.5
1972	19.0	10.9	11.4	2.2	43.5
1973	21.2	6.9	8.7	3.7	40.5
21 CLAMSHELL DREDGES					
1970	11.5%	12.5%	11.5%	-	35.5%
1971	14.8	11.3	9.0	-	35.1
1972	14.9	10.7	10.6	-	36.2
1973	10.4	5.4	13.7	-	29.5
14 DIPPER/DRAGLINE DREDGES					
1970	6.6%	10.4%	9.7%	-	26.7%
1971	8.6	14.1	6.2	-	28.9
1972	25.0	2.3	3.6	-	30.9
1973	17.7	1.1	5.3	-	24.1

FIGURE 11

Yearly Summary of Project Utilization
By Customer and Dredge Type

Year	Corps of Engineers	Ports and Munic.	Industrial Concerns	Other	Total
	Time Utilized by Customer Classification				
Hydraulic					
1970	57%	20%	22%	1%	100%
1971	68	18	13	1	100
1972	46	30	23	1	100
1973	56	28	16	-	100
Clamshell					
1970	10	50	40	-	100
1971	32	40	28	-	100
1972	47	24	29	-	100
1973	51	18	31	-	100

information for the entire ten-year period and only eight furnishing data for the years 1970-1973. The limited data did not permit ADL to develop any broad understanding of cost per cubic yard figures for each type of dredge, type of customer, and work category. Consequently, it was concluded that a meaningful analysis of industry cost was not possible due to the lack of detailed data and supporting information.

e. Industry Profits.

The survey of industry profits ran into the same difficulties as the survey of costs. Dredging companies generally do not maintain records over an extended period and thus were unable to furnish information on assets, revenues or profits over the ten year period. Nonetheless, an analysis was undertaken based on the limited available data. The analysis indicates that profits, before taxes, ranged from 14.6% of revenues in 1972 to 8.8% in 1973. From the standpoint of the return on assets, industry representatives indicated that, as a rule, for the kind of equipment required, dredging requires $1 of assets for $1 of revenues. Using this ratio as a basic assumption, although the sample used was largely derived from profitable dredging companies, the average return on assets did not equal that experienced by the construction industry. Thus, it was concluded that the indicated low level of profits, taken with the significant decline in workload has aggravated the long-term industry problem of generating sufficient capital for the replacement of plant and equipment.

3. PART II - FUTURE REQUIREMENTS AND PROCEDURES (1974-1983)

A significant part of the National Dredging Study effort was directed toward developing a forecast of dredging requirements in the United States over the period of 1974-1983. The principal source of data for the federal portion of this projection were the Corps of Engineers districts. The information on the non-Federal portion of the forecast was obtained from port authorities, state and local agencies, public utilities and private companies.

a. Corps of Engineers Dredging Requirements.

Both volume and cost estimates were developed for the Federal dredging program wiht the latter expressed in terms of 1973 dollars and no provision for any cost escalation factor. Estimated expenditures for dredging, under both the contract and hired labor portions of the overall Corps program, including costs for applicable surveys and administration, in addition to operational costs. The distribution between projected contractor and hired labor work was provided by the individual Corps districts based on past experience and prevailing practices, independent of the future availability of Corps-owned plant and/or satisfactory contractor bids.

The Corps-wide dredging volume over the ten-year period is forecasted to increase from 420 million cubic yards in 1974 to a peak of 670 million cubic yards in 1979, when anticipated annual requirements should level off at about 590 million cubic yards through the remainder of the period. The distribution by region of the total estimated volume for the ten-year period is shown in Figure 12.

The total annual cost of Federal dredging was estimated at $230 million in 1974, and $420 million in 1979; after which annual expenditures are expected to decrease for the rest of the time period reaching $315 million in 1983. The estimated total dredging expenditures over the ten-year period are distributed by region as shown in Figure 13.

As indicated in Figures 12 and 13, about 60% of the overall dredging volume is scheduled for the Gulf Coast area, while the cost of this work is estimated to be only 41% of total dredging expenditures, reflecting significantly lower unit prices for the Gulf Coast region, as compared to other regions of the country.

Over the ten-year period nearly 3-1/3 billion cubic yards, or about 60% of the Corps-wide total work, is forecasted to be maintenance dredging. The annual maintenance workload is expected to be relatively stable during the years 1974-1980, varying between 302 and 335 million cubic yards per year. After 1980, the estimated annual maintenance volume is expected to increase sharply at a rate of about 8.5% per year due to increased maintenance requirements attributable to new work scheduled for construction during the previous years.

FIGURE 12

FORECAST OF FEDERAL DREDGING - VOLUME DISTRIBUTION BY REGION

	10-Year Volume (10^6 c.y.)	Percent of Corps-Wide Volume
GULF COAST	3,318	60.1
INTERIOR WATERWAYS	856	15.5
EAST COAST	843	15.3
WEST COAST	405	7.3
GREAT LAKES	102	1.8
CORPS-WIDE TOTAL	5,524	100.0

FIGURE 13

FORECAST OF FEDERAL DREDGING - EXPENDITURES DISTRIBUTION BY REGION

	10-YEAR EXPENDITURES (MILLION)	PERCENT OF CORPS-WIDE EXPENDITURES
GULF COAST	1,404	41.1
EAST COAST	1,085	31.8
INTERIOR WATERWAYS	395	11.6
WEST COAST	329	9.6
GREAT LAKES	202	5.9
CORPS-WIDE TOTAL	3,415	100.0

New work is expected to total about 2.2 billion cubic yards over the entire ten-year period, or nearly 40% of the overall dredging workload. Annual new work requirements are forecasted to vary substantially from 104 million cubic yards in 1974 to 348 million cubic yards in 1979, and to 193 million cubic yards in 1983.

Hired labor dredging is expected to aggregate 1-3/4 billion cubic yards, about 32% of the whole, over the ten-year period, while a total of over 3-3/4 billion cubic yards, or about 68%, is forecasted for accomplishment under contract.

The amount of hired labor work is expected to increase relatively steadily at about 4.4% per year from 150 million cubic yards in 1974 to 220 million cubic yards in 1983.

Although it is indicated that contract work, on a volumetric basis, will amount to more than twice the hired labor work, the annual workload to be contracted is expected to fluctuate widely due to variations in the new work program. It is estimated that the annual volume of contract dredging will be 270 million cubic yards in 1974, increasing to 480 million in 1979 and then decreasing to 370 million cubic yards in 1983, as the volume of new work diminishes.

From the standpoint of expenditures, the hired labor portion of the planned work is estimated to total $813 million or about 24% of the overall program cost for the ten years. While the contract work is estimated at more than $2.6 billion, or about

76% of the total cost of the dredging program forecasted for the period 1974-1983.

The bulk, over 90% of the hired labor volume and expenditures over the ten years, is expected to be related to the operation of hopper and dustpan dredges, which are types of dredges developed by the Corps of Engineers to meet unique dredging requirements.

In the case of contract work, the hydraulic cutterhead dredge is predominant, as indicated in Figure 14 which shows the anticipated distribution of volume and cost by types of industry dredges.

About 92% of the Corps-wide dredging volume or 89% of the expenditures in any one year is expected to be required on navigation projects. Averaged over the ten-year period, the percentage distribution of the total forecasted federal workload by types of projects, such as navigation, flood control and beach nourishment is shown in Figure 15.

b. Non-Federal Dredging Requirements.

As addressed in the National Dredging Study, this market includes all work done by floating dredging plant sponsored by private companies, port authorities, public utilities, state and local agencies, and all Federal agencies, except for the work administered by the Corps of Engineers. Also excluded from this market is work done by port authorities and other public agencies with their own dredging plant, as well as commercial

FIGURE 14

FORECAST OF FEDERAL DREDGING - CONTRACT WORK

DISTRIBUTION BY TYPE OF DREDGE

	PERCENT OF 10-YEAR VOLUME	PERCENT OF 10-YEAR EXPENDITURES
CUTTERHEAD DREDGES	94.2	86.4
CLAMSHELL DREDGES	4.4	11.4
HOPPER DREDGES	1.3	1.7
DIPPER DREDGES	0.1	0.5

FIGURE 15

FORECAST OF FEDERAL DREDGING CLASSIFIED BY TYPE OF PROJECT

	PERCENT OF 10-YEAR VOLUME	PERCENT OF 10-YEAR EXPENDITURES
NAVIGATION	92.2	89.3
FLOOD CONTROL	5.7	3.8
BEACH NOURISHMENT	2.0	6.5
DISPOSAL AREAS	0.1	0.2
WATER RESOURCES	0.03	0.2
POWER DEVELOPMENT	0.0	0.0

sand, gravel and shell dredging. In effect, the non-Federal dredging market is that which is available to the dredging industry from sources other than the Corps of Engineers.

The non-Federal dredging market is generally diffuse. In addition, the information gathered by ADL lacks the completeness of the information furnished for the Federal segment of the dredging program. With these stated reservations, ADL estimated the non-Federal dredging workload would average 153.6 million cubic yards per year for the ten-year period with most of it, about 75% occurring in the Gulf and East Coast regions. The distribution of this annual workload by region is shown in Figure 16. As indicated in this figure, in all regions except the Great Lakes, most of the work is expected to be accomplished with hydraulic cutterhead dredges.

c. Forecast of All Dredging - Federal and Non-Federal.

A graphical presentation of the future outlook for the overall dredging volumes, both Federal and non-Federal, is shown in Figure 17. The non-Federal portion of this forecast is based on an estimated average annual requirement of 154 million cubic years per year, whereas the Federal forecast varies considerably from year to year, with the peak year occurring in 1979. Annualizing the Federal dredging forecast, and adding it to the yearly non-Federal volume, an average of 706 million cubic yards of dredging is predicted for each year, of which 531 million cubic yards (or roughly three-quarters) is forecasted for accomplishment by the industry.

FIGURE 16

NON-FEDERAL DREDGING QUANTITIES

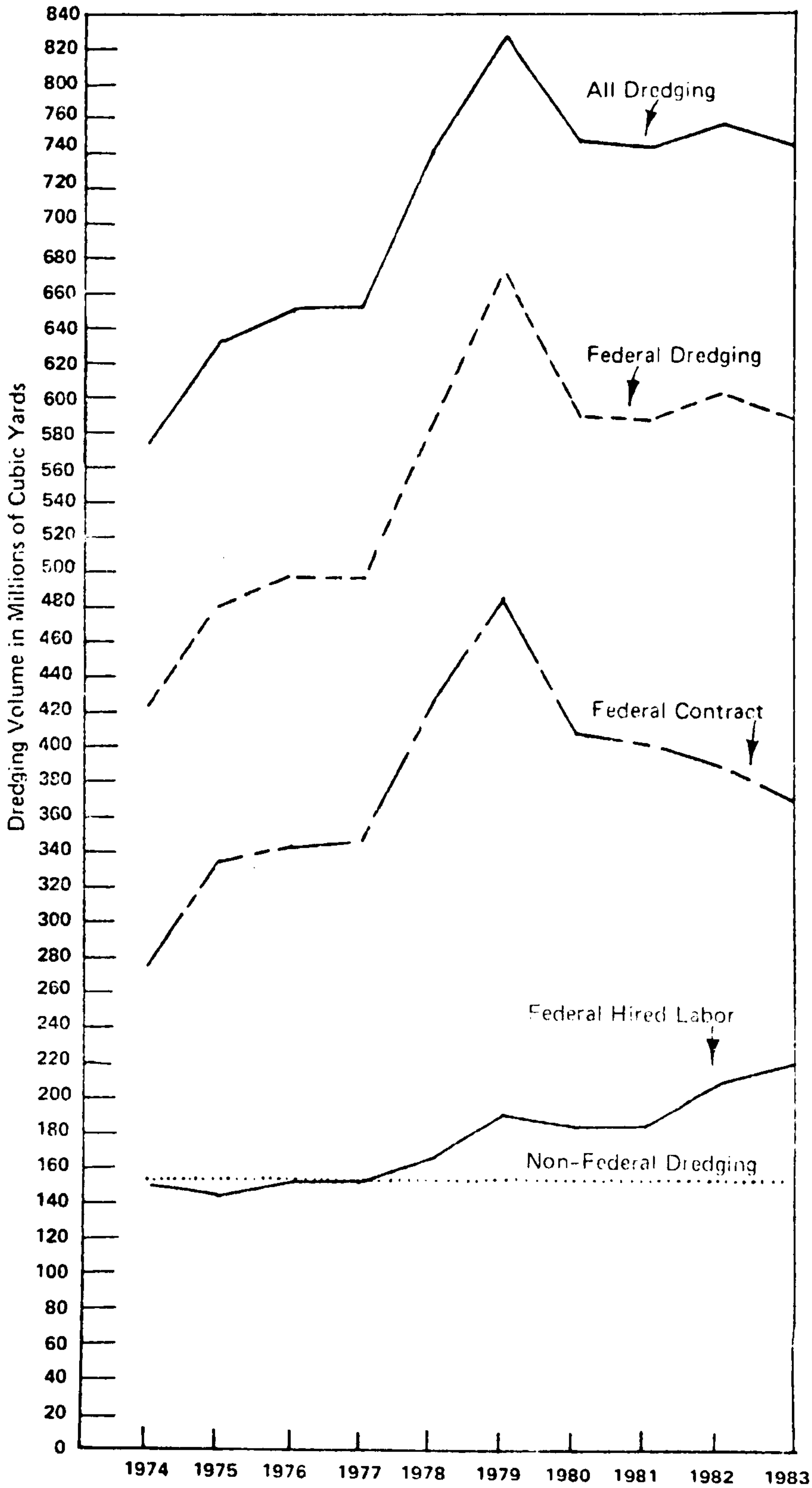
AVERAGE ANNUAL FORECAST FOR THE PERIOD 1974 - 1983

(10^6 CUBIC YARDS)

REGION	HYDRAULIC CUTTERHEAD	CLAMSHELL
WEST COAST	17.4	4.7
GULF COAST	54.1	7.0
INTERIOR WATERWAYS	9.9	1.3
GREAT LAKES	0.3	0.7
EAST COAST	36.0	22.2
TOTAL	117.7	35.9

FIGURE 17

FORECAST OF ALL DREDGING--FEDERAL AND NONFEDERAL



d. Assessment of Dredge Capability.

ADL performed an analysis of the capacity and demand for both Corps and industry dredges, in order to determine if additional equipment would be required to meet future requirements.

With regard to the Corps of Engineers ability to meet the anticipated volume of hired labor work, ADL concluded that:

(1) As many as 9-11 additional nominal-size, 3,000 cubic yards capacity, hopper dredges would be required by the Corps to supplement the current fleet of 15 dredges. The forecast indicated that these dredges should be added to the existing fleet at the rate of one a year, commencing in 1975.

(2) The present fleet of 8 dustpan dredges was judged to be inadequate because of age and obsolescence. The level of projected workload in the Mississippi, Missouri and Ohio Rivers, for which this unique type of dredge is best suited, indicates that the present fleet of dustpans should be replaced and supplemented during the period of 1979-1983 by 5 to 6 additional dustpan dredges capable of digging to increased depths.

(3) The present fleet of 15 cutterhead dredges was judged to be inadequate because of age and obsolescence, except for the smaller dredges, with discharge diameters of 12 inches or less. All of the six larger cutterhead dredges, with discharge diameters

of 20 inches or more, were considered to be obsolete. However, the study does not indicate a need for any additional units due to the large number of cutterhead dredges available from the industry.

(4) The three sidecaster dredges that are used principally along the East Coast for the maintenance of narrow, shallow and exposed coastal inlet bar channels appear to be meeting the demands, and no additional units are included in the ADL forecast.

(5) The five clamshell dredges and two dipper dredges that the Corps presently owns were considered to have sufficient capacity to meet anticipated demands, when related to the large number of these dredges available in the Industry.

In order to assess the dredge capability of the industry, ADL inventoried the privately owned dredges, and identified a total fleet of 457 dredges. The fleet is comprised of 264 hydraulic cutterhead, 161 clamshell, 13 dipper and 19 hydraulic plain suction dredges. This inventory does not include 250 small portable dredges owned by the National Car Rental Company and the large number of dredges used exclusively for sand, gravel, and shell mining. The regional distribution of the industry fleet is shown in Figure 18.

FIGURE 18

CONTRACTOR DREDGE INVENTORY: REGIONAL DISTRIBUTION

Region	Hydraulic Cutterhead		Clamshell		Dipper	
West Coast	38	(14%)	53	(33%)	1	(8%)
Gulf Coast	75	(28%)	23	(14%)	0	(0%)
Interior	31	(12%)	33	(21%)	5	(38%)
Great Lakes	23	(9%)	28	(17%)	4	(31%)
East Coast	97	(37%)	24	(15%)	3	(23%)
TOTAL	264	(100%)	161	(100%)	13	(100%)

As previously noted, the hydraulic cutterhead dredge is the predominant type of equipment in use in this country. Many of the existing cutterhead dredges are well past a normal 20-year useful life. However, contractors have managed to keep them operative with extensive refitting, rebuilding and repowering. Seventy of the 264 cutterhead dredges in the present inventory were inspected by ADL representatives and found to vary greatly in condition, with many of the smaller dredges being idle for long periods and requiring extensive overhaul for reactivation. By contrast, the larger, deep-digging, high production dredges were being maintained in good mechanical repair. It is clear that the industry believes that operational efficiency, profits and future contracts depend mainly on the maintenance of their large dredging plant, and service these units accordingly.

ADL concluded that unless there is a drastic change in dredging needs, the present industry fleet has the ability to meet the private and federal requirements as well as some of the foreign dredging demands. However, it was noted that only one newly constructed cutterhead dredge has the capability of dredging at optimum efficiency in channel depths of over 70 feet.

In this regard, in discussing the outlook for deepwater terminals in the United States, ADL indicated that given the present oil import situation, very few domestic deepwater terminals are expected to be constructed during the ten-year forecast period. Further, with few exceptions, the locations being considered for such terminals would involve minimal dredging since they are expected to be the offshore type. It thus appears that the importance of deepwater terminal related dredging, when compared to the overall dredging market, will not, in itself, have a significant impact on the dredging workload over the next decade.

Based on a demand and capacity analysis for each region, for each forecast year, and for each dredge type and size; ADL concluded that the existing industry capability was more than adequate to perform the scheduled volume of Federal work during the entire ten-year period, except in the case of cutterhead dredges in the 1979-1983 period, when shortages are forecasted to occur in the larger size, (22" to 30"), equipment. With respect to non-Federal work, a large margin of excess capacity is indicated and ADL concluded that all forecasted non-Federal work could be completed with the existing industry fleet.

e. Dredging Technology.

In conjunction with assessing the Corps and industry dredging fleets, ADL personnel met with dredge designers, builders and operators and surveyed dredges in England, Holland, France, Belgium, and West Germany to acquire a comparative base for an evaluation of U.S. dredging technology. As a result, a number of features incorporated in some of the newer European hopper dredges, such as horizontal sliding dump doors, submerged drag-head-mounted dredge pumps and complete automation and instrumentation were cited as advancements that should be considered for installation on U.S. hopper dredges. However, the study indicates that dredging technology and expertise in the United States is at a high level. The limited number of new dredges being constructed was considered to result from the limited annual dredging budget for maintenance dredging, a drastic reduction in the number of new work or improvement dredging projects and the absence of any major deep water port facilities, such as Europort and Gulf de Fos.

No revolutionary dredge design concepts appear to be imminent. However, there is an effort, both by the Corps of Engineers and the industry, being concentrated on the extension or modification of proved designs, which would increase production and reduce operating costs. A few of the most promising design features under consideration are:

(1) Extended or articulated ladders and dragarms.

(2) Submerged dredge pumps.

(3) Automated dredge operations.

(4) Greater utilization of process instrumentation.

In discussing the application of potential improvements in dredging equipment, ADL indicated that the dredging industry has dropped to a level of activity and profitability that makes modernization difficult and tends to cause plant to fall below best standards. The study concludes that while dredging requirements on the whole will continue to be met, there is little prospect of significantly improving productivity without introducing modern equipment into the dredging field.

f. Allocation of Work.

In considering future requirements for dredging, ADL explored various alternatives of how the Corps dredging program might be shared. After considering several methods of comparing the effects of changes in the share of work done with Corps plant and with industry plant, ADL adopted an approach which was based largely on equipment utilization. In this analysis, ADL concentrated their efforts in the hopper and cutterhead areas since these are the predominant types of dredges.

The forecasted Corps dredging programs for three selected years, 1974, 1979 and 1983 were analyzed. The estimated costs to the Government of varying the allocations of the projected Federal dredging workload are presented graphically in Figure 19. This figure indicates that the total program cost would be less in all instances if Corps plant were utilized to accomplish 100% of the workload.

The effect of varying the Corps/Industry workload or yardage allocations through intermediate levels, 75/25, 50/50 and 25/75, generally follows the same trend in each of the annual graphs. The lowpoint in each of the years, other than the 100% allocation

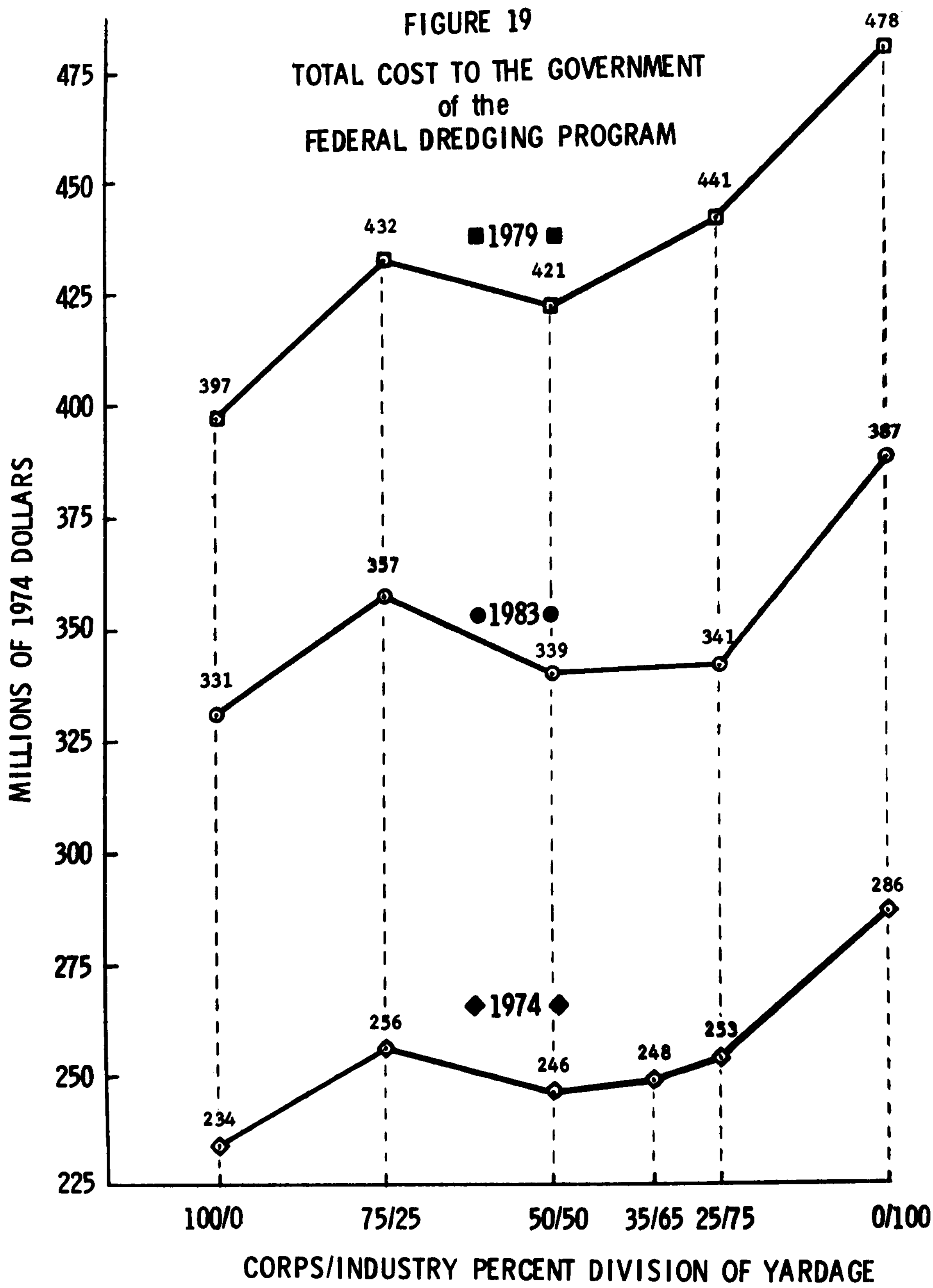


FIGURE 19
TOTAL COST TO THE GOVERNMENT
of the
FEDERAL DREDGING PROGRAM
MILLIONS OF 1974 DOLLARS
475
450
425
400
375
350
325
300
275
250
225
1979
1983
1974
478
441
432
421
397
387
357
341
339
331
286
256
253
248
246
234
100/0
75/25
50/50
35/65
25/75
0/100
CORPS/INDUSTRY PERCENT DIVISION OF YARDAGE

to the Corps, appears to be 50/50. In spite of this indicated favorable distribution, which considers both the capital investment and operating cost requirements, the ADL study concludes that a 25% Corps - 75% industry, trending toward 35% Corps/65% industry in future years, would appear to be the most favorable division of the workload between the Corps and industry.

Considering the size and condition of the existing fleets of the Corps and the industry, the effect of varying the workload distribution through intermediate levels on the capital investment requirements is shown in Figure 20. Based on this aspect, the study indicates that the optimum Corps/industry division of the workload is in the range of 25/75% to 35/65%. In connection with the division of the workload, it is concluded that any appreciable change in the allocation policy should be accompanied by a planned transition period of about ten years.

4. PART III - CORPS ESTIMATING AND BIDDING PROCEDURES

ADL performed an evaluation of the estimating and bidding procedures of the Corps as related to applicable public laws and regulations. In addition to examining and analyzing the records of bids and estimates on jobs advertised during 1964-1973, the aspects of the estimating and bidding procedures were discussed with Corps, industry and port official representatives. Also, a number of public meetings were held, under the auspices of the Advisory Committee, at which the various views of all interested parties were solicited and considered.

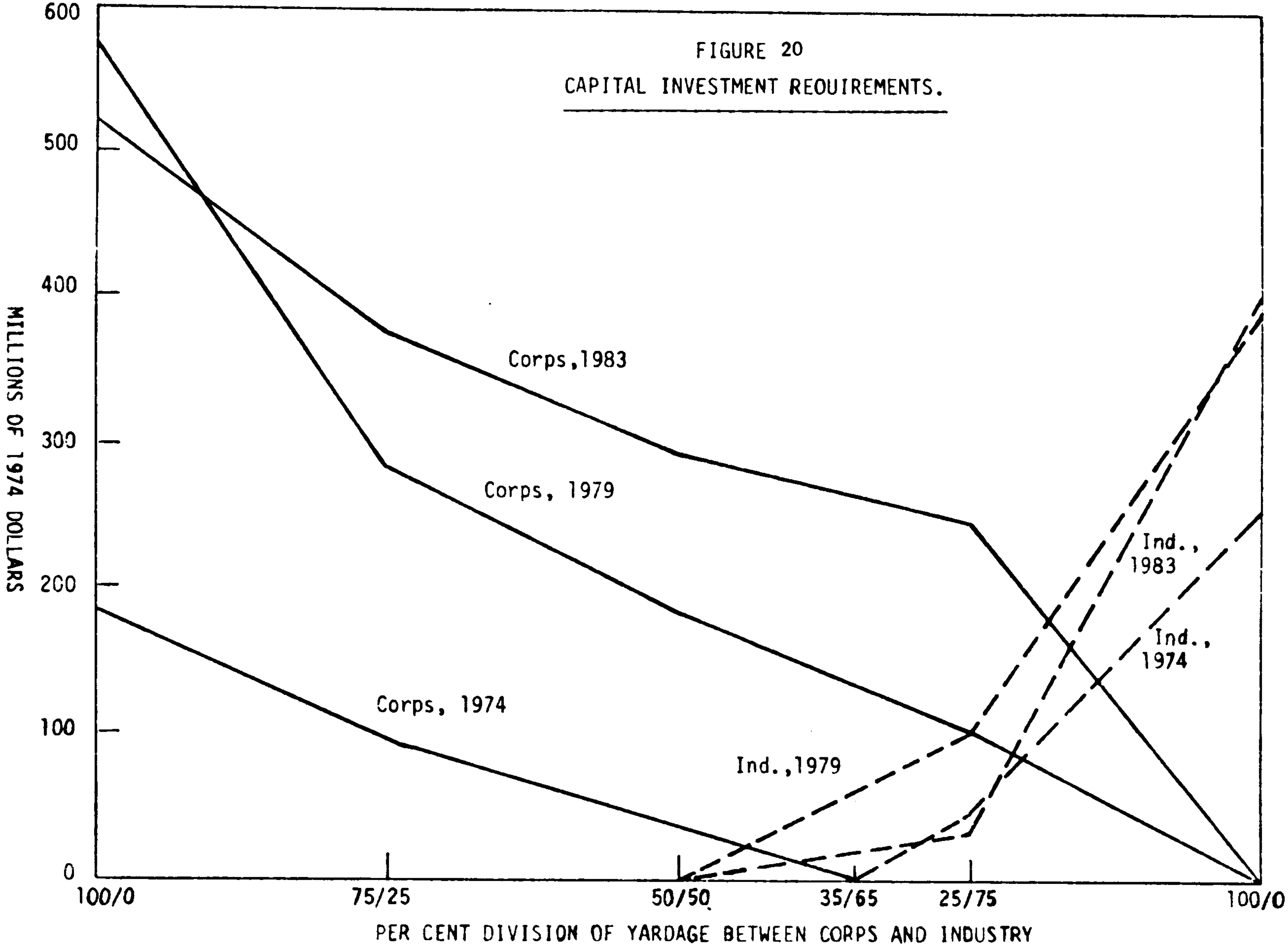


FIGURE 20

CAPITAL INVESTMENT REQUIREMENTS.

The basic law governing the work of the Corps of Engineers is codified in Title 33 of the U.S. Code which prohibits the Corps from performing work under contract "if the contract price is more than 25 per centum in excess of the estimated cost of doing work by Government plant." Where Federal plant is not available, the Corps policy in evaluating industry bids has been to use estimates based on fair and reasonable costs, exclusive of profit, to a well-equipped contractor.

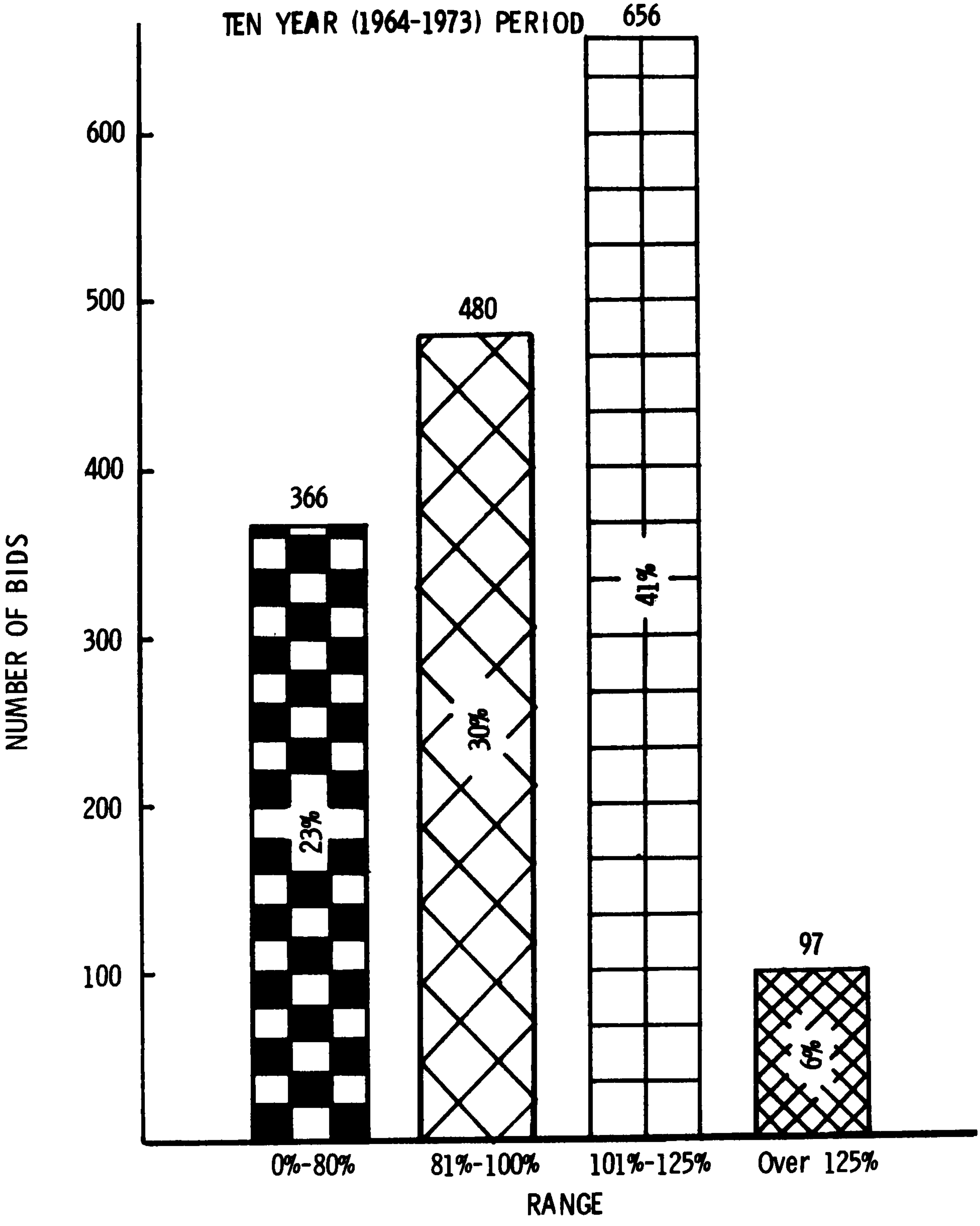
Over the period of 1964-1973, a total of 1,599 jobs were advertised which resulted in the award of 1,534 contracts or about 96% of the total advertisement. In nearly all of the 1,599 bid invitations, 98%, the Corps estimates were prepared on the "well-equipped contractor" basis. This type of estimate is based on the use of a specific type of industry equipment to accomplish the job requirements as stated in the specifications. The preparation of this type of estimate involves the calculation of dredge performance and output, plant rental and all other operating costs, mobilization and demobilization costs, and provision for all applicable miscellaneous expenses, other than profit.

A summary, showing the distribution of the ratio of the low industry bids to the 1,599 Corps estimates during the period of 1964-1973 is presented in Figure 21. This figure indicates that 366 or 26% of the bids were less than 80% of the Corps estimates,

FIGURE 21

DISTRIBUTION OF THE RATIO OF THE LOW BID TO THE GOVERNMENT ESTIMATE

TEN YEAR (1964-1973) PERIOD



30% or 480 bids were in the range of 80% to 100% of the Corps estimate, 41% or 656 of the bids ranged from 101% to 125% of the Corps estimate, and only 6% or 97 of the bids exceeded 125% of the Corps estimate and thus could not be awarded at the time the bids were received due to the provision of the statutory limitation on awards referred to in the previously mentioned Title 33 of the U.S. Code. In only 27 of the 97 instances, in which the bids exceeded the statutory limitation, were protests lodged by the bidders. After a thorough examination of the factors involved, 8 of the 27 protest cases were then awarded to the industry.

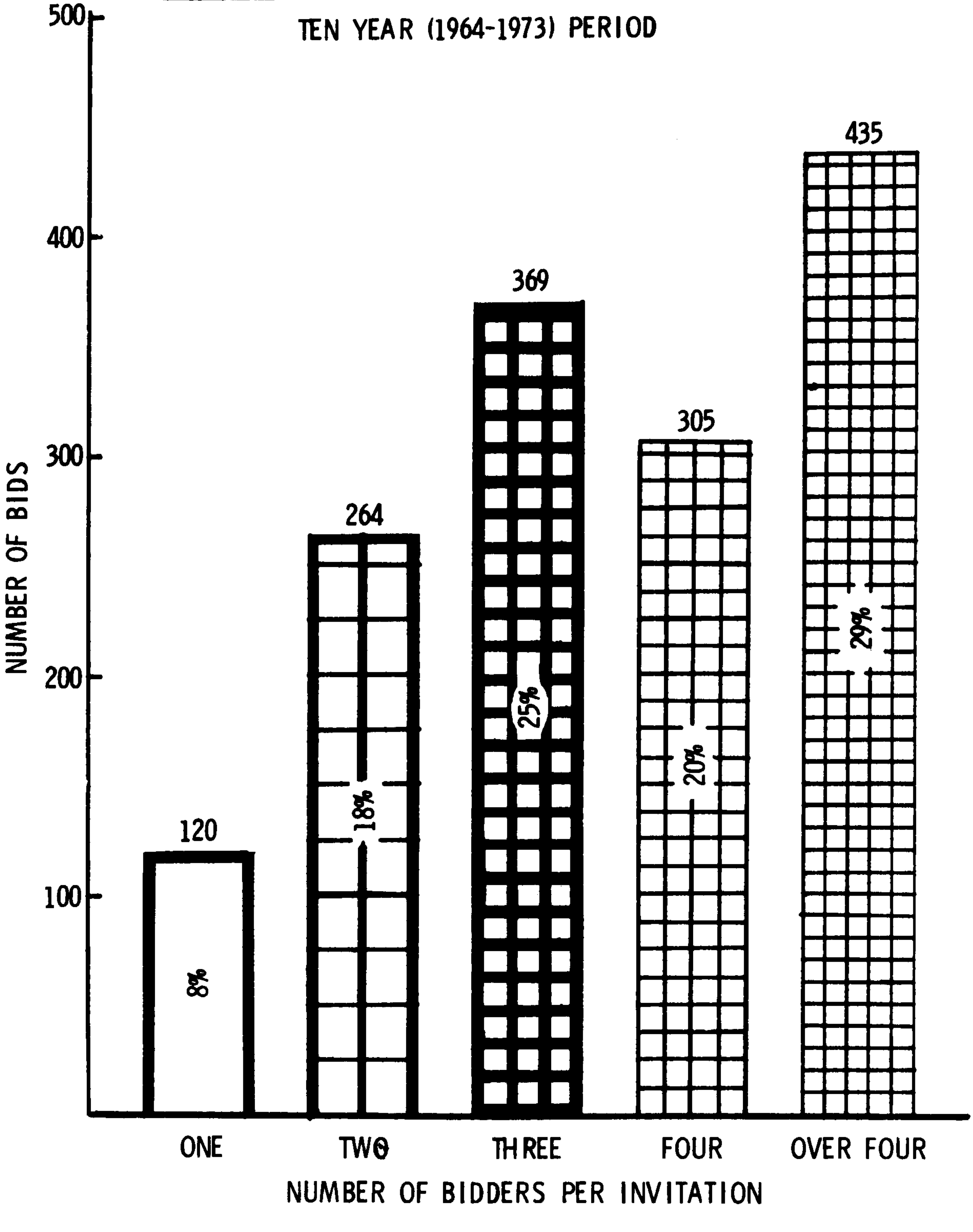
A similar summary, showing the number of bids received on each of the 1,493 invitations, in which complete data was available, is presented in Figure 22. This figure indicates that in 435 instances or 29%, bids were received from five or more contractors, four bidders responded in 305 cases or 20% of the invitations, three bidders responded in 369 cases or 25% of the invitations, two bidders responded in 264 instances or 18% of the invitations and only one bidder responded in 120 instances or 8% of the 1,493 invitations.

Only a small number, 26, of the 1,599 jobs advertised were issued on a hired labor cost estimate basis. Fundamentally, the preparation of hired labor estimates involves the calculation of costs that would be incurred using a Corps dredge to perform the

FIGURE 22

NUMBER OF BIDS RECEIVED ON EACH INVITATION

TEN YEAR (1964-1973) PERIOD



scheduled work. Eleven or 42% of the 26 invitations prepared on a hired labor estimate basis were within the statutory limitation and thus were awarded to the industry.

Over the ten-year reference period, 669 of the 1,599 invitations for bids were advertised as Small Business set-aside work. The study indicates that while the number of set-aside projects has not increased appreciably during the ten years, the dollar volume awarded increased 109%, from $14.1 million to $29.5 million. By contrast, there was a 1% decrease in the total volume of awards available to industry firms not qualifying under the Small Business criteria. The study concludes that the Corps should examine the Small Business set-aside program to determine whether the program is being administered uniformily by the various Districts. The study also concludes that open advertisement of some of the larger set-asides jobs would result in cost savings.

The vast majority (over 90%) of the contracts awarded the industry are on a unit price or cost per cubic yard of material removed basis.

With regard to survey and inspection procedures, ADL found that the Corps establishes the same work objectives for itself as for the industry. Engineering and design information, which establish such objectives for dredging, were found to be identical. However, due to legal and contractual provisions, more detailed specifications are required to protect both the Corps and the industry for that portion of the work performed by the industry. Since contractors usually receive their payments on the basis of after-dredging survey data, and are liable for variations in performance, the Corps generally gives first priority to Industry surveys. Thus, surveys associated with Corps plant are often delayed for significant periods, which leads to some incomparability in costs, making it difficult to make any meaningful comparison of Corps costs with industry dredging costs.

5. SUMMARY

I would like to emphasize that the materials, findings and conclusions discussed in this paper are those included in the report prepared by the management-engineering firm, Arthur D. Little. In some instances, the ADL views are different from those of the Advisory Committee and the Chief of Engineers. The views of the Advisory Committee and the Chief of Engineers are included in separate documents, and have not been referred to in my talk today, since they are still under review by the Secretary of the Army staff and the Office of Management and Budget staff.

In brief, the salient features of the ADL report on the National Dredging Study are as follows:

a. The preparation of the Study was directed by the Congressional Committees on Appropriations to determine the best course of action to assure a viable dredging program in the United States.

b. The Corps dredging fleet is largely obsolete.

c. The industry has an excess of production capability in all classes of equipment, except for hopper, dustpan and side-casting dredges.

d. The significant decline in the level of new work, or improvement dredging workload, has resulted in excessive idle time for industry plant since 1964. As a result, the industry has been experiencing a difficult adjustment period of contraction and consolidation.

e. The profit margin of the industry is low when compared with general construction and manufacturing organizations.

f. The Corps/industry distribution of the annual workload during the reference period ranged from 32/68% to 39/61%. The study indicates the most favorable long-term Corps/industry distribution, considering both capital requirements and the cost of dredging operations, is in the range of 25/75% to 35/65%.

g. The application of constant dollar indices indicates that the annual dredging expenditures in 1973 were about one-half those of 1964.

h. The majority of the industry is composed of small business firms.

i. Environmental constraints and considerations have served to limit the scope of the nation-wide dredging program.

j. The forecast of future workload requirements indicates a substantial increase during the next decade, with the Gulf and East Coast regions providing the greatest potential.

k. There is an indicated shortfall of 9-11 hopper dredges and several dustpan dredges during the next ten years.

l. Most of the deep-draft terminals being considered are the off-shore type. Thus, the dredging required for these facilities appears to be minimal.

m. U.S. dredging technology is adequate. The limited annual dredging programs, and the absence of any requirements to construct new, major port facilities such as Europort and Gulf de Fos, have limited the opportunities to apply existing design technology.

n. Variances in survey and inspection procedures make it difficult to make any direct comparisons of the costs of Federal and industry plant.

In closing, it is my view, that the National Dredging Study has served to highlight many important facets of the dredging program, which were obscure due to the fact that many of the basic reference materials were not available in an assembled form.

The study has already improved the level of communication and understanding between the Corps and industry. I believe that continued joint usage of the vast amount of information contained in the study, will lead to the evolution of an optimum dredging program in the United States - which will be a major step toward the Corps objective of "BUILDING TOMORROW TODAY".

AN INVESTIGATION OF THE ENVIRONMENTAL IMPACTS ASSOCIATED WITH THE DISPOSAL OF DREDGED MATERIAL AT THE OFFSHORE DISPOSAL SITE, GALVESTON, TEXAS*

by

David B. Mathis** and Stephen P. Cobb**

ABSTRACT

The Environmental Effects Laboratory (EEL) of the Waterways Experiment Station (WES), in conjunction with the Galveston District, Corps of Engineers, has established a field research study at the offshore dredged material disposal site near Galveston, Texas. This site is one of four regional study sites established by the EEL for the purpose of evaluating the environmental impacts associated with the open water disposal of dredged material. In order to effectively evaluate these impacts in terms of cause and effect relationships, a comprehensive research effort is being undertaken at the site and at adjacent areas to the site in order to define natural and unnatural changes in the sediments and water column, and the associated flora and fauna of each. Particular emphasis is being placed on determining the significance of certain physical, chemical, and biological factors that govern the rate and extent by which dredged material disposal sites are colonized by benthic organisms.

Relative to the disposal operation itself, the investigation is divided into three phases. Phase I, a pre-disposal investigation, is designed to evaluate baseline conditions at the study site, and to formulate an experimental design for Phase II, controlled disposal investigations. The controlled disposal

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* Complete paper was not received from the authors.

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investigations of Phase II involve a short-term, intensive sampling effort, designed to evaluate possible acute environmental impacts associated with dredged material disposal. The longer-term, monitoring efforts of Phase II are designed to evaluate possible chronic environmental impacts associated with dredged material disposal.

This paper describes contracted physical, chemical, and biological research undertaken at the study site during the Phase I investigations and discusses the experimental design formulated for the Phase II investigations, utilizing controlled disposal techniques. The paper will also present a recent history of dredged material disposal activities by the Corps of Engineers within the northern Gulf of Mexico, as well as an overview of planned research to be undertaken at the site by EEL.

USE OF REMOTE SENSING IN EVALUATING TURBIDITY PLUMES

by

Dr. Wesley P. James*

ABSTRACT

This paper will discuss the use of 35 mm airphotos to quantitatively evaluate turbidity levels and measure water current velocities. Most dredging takes place under continually varying conditions. The material dredged is not homogenous, normal operations produce variations and winds and currents may vary. Interpretation of individual point measurements of water quality parameters become more of a problem under these varying conditions. Aerial photography offers a method to obtain an overview of the operation.

An aerial photograph provides a record of a portion of the earth's surface from an elevated vantage point with a spatial resolution many times that of the unaided human eye. It is not limited to determination of size and position of objects as in normal photogrammetry but it can also be used as an energy sensor. The amount of light reflected from the water column is recorded by the normal film, or infrared-sensitive film, as film density which can be quantitatively measured with photodensitometers. Aerial photography will provide an instantaneous record of a dynamic system and a permanent record for later analysis. Turbidity is a measure of light scatter within the water column and is the most obvious water quality parameter to be quantitatively measured with aerial photography. These techniques have been shown to be effective tools in the study of dispersion of wastes from ocean outfalls and remote measurement of turbidity.

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INTRODUCTION

Water pollution can be defined as the discharge or release of any material into the water which adversely affects its physical, chemical or biological characteristics. The quality of surface water is affected by both natural factors and activities of man. Primary sources of waste into our waterways are municipal, industrial and agricultural. As shown in Figure 1, the waste inputs include heat, metals, toxic chemicals, oil, sediments, nutrients, organic material and bacteria. The pollutants can cause toxicity, increased BOD, low dissolved oxygen, bacterial contamination, increased temperature, turbidity, color and surface films. Perhaps the most critical water quality parameters are toxicity, dissolved oxygen and bacterial contamination. These parameters can not be measured directly by remote methods but color, turbidity, surface films and surface water temperature can. Under certain conditions indirect relationships with the other parameters might be developed.

Color and turbidity are perhaps the most obvious water quality parameters to be quantitatively measured by remote techniques. True color in natural waters generally results from contact with organic debris. Surface waters may also become colored by pollution with highly colored waste waters such as those from dyeing operations in the paper industry or from beet processing in the canning industry.

REMOTE SENSING

The intensity and composition of the light that is scattered from within the water column can be utilized to estimate color and turbidity of the water. The primary source of this light is the sun. Some of

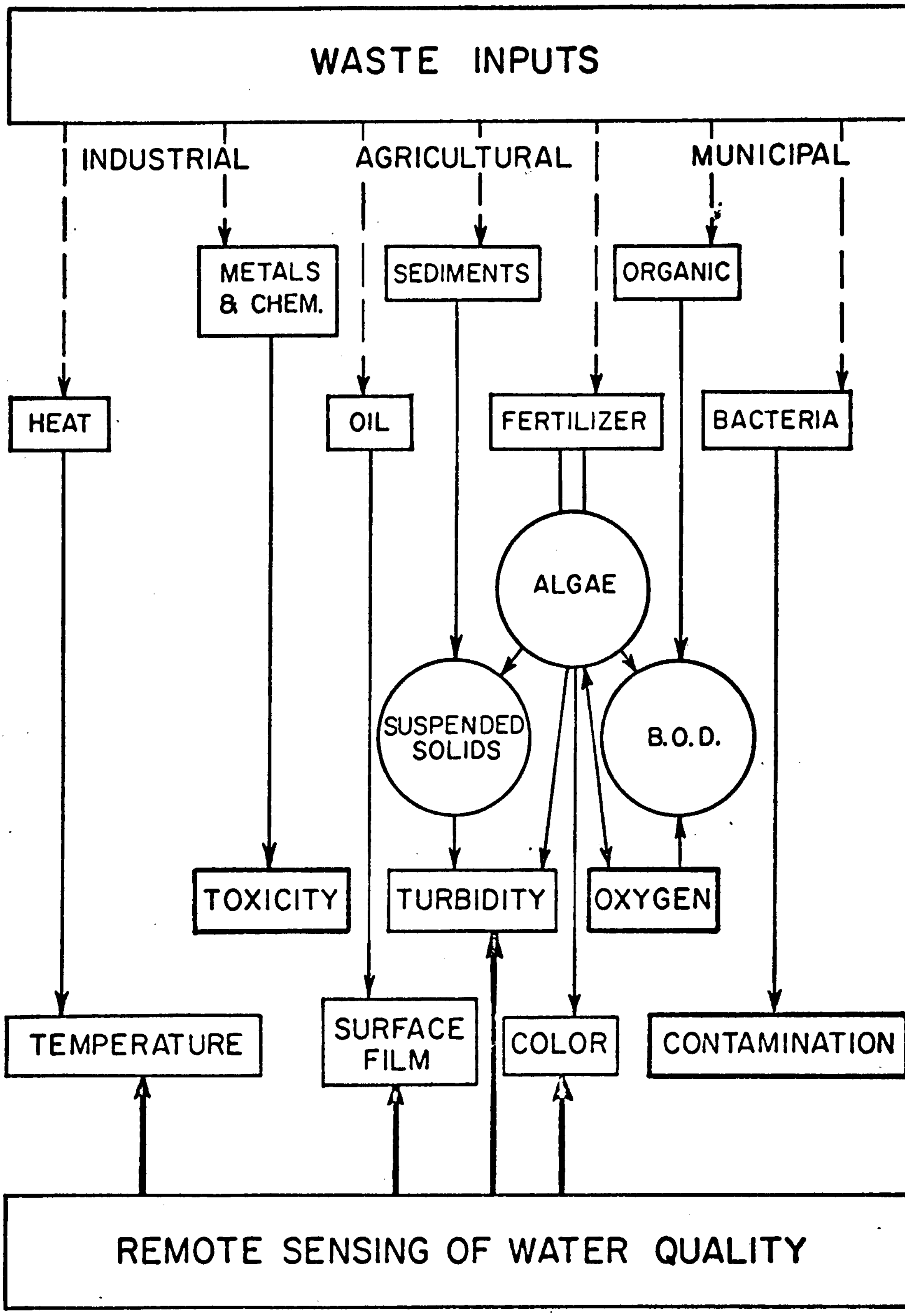

Figure 1. Aerial Monitoring of Water Quality

the light is scattered and absorbed as it passes through the atmosphere. As a result, incident light at the water surface includes both direct sunlight and skylight. Skylight is blue for a clear sky but may be nearly white when the atmosphere is hazy or the sky cloudy. The intensity and composition of the direct lighting also varies with the time of day or sun altitude and atmospheric composition.

As shown in Figure 2, the return of light that reaches the airborne sensor can include energy reflected from the bottom of the water body or reflected from within the water, reflected light from the water surface, and light scattered in the atmosphere. Light reflected from the water surface yields information on the water surface geometry, surface films, floating debris and water roughness but yields little information on the water column characteristics. The reflected light from the water surface will be partially polarized parallel to the horizon and a polarizing filter can be used to minimize the light return from the surface of the water.

Since the light scattered in the atmosphere is predominantly blue, the effect of light path radiance can be reduced by using a minus blue filter. The subsurface light may include both return from the volume scattering within the water and reflection from the bottom. The intensity and composition of the light scattered within the water column is related to the characteristics of the suspended and colloidal material in the water.

Airborne sensors, unlike the spectrophotometer used in the laboratory analysis of water samples, measure the scattered light rather than the transmitted light through the water column. Bands of strong absorption in the transmitted light will usually appear as absorption bands in the scattered light. Variation in return can be caused by a variation in

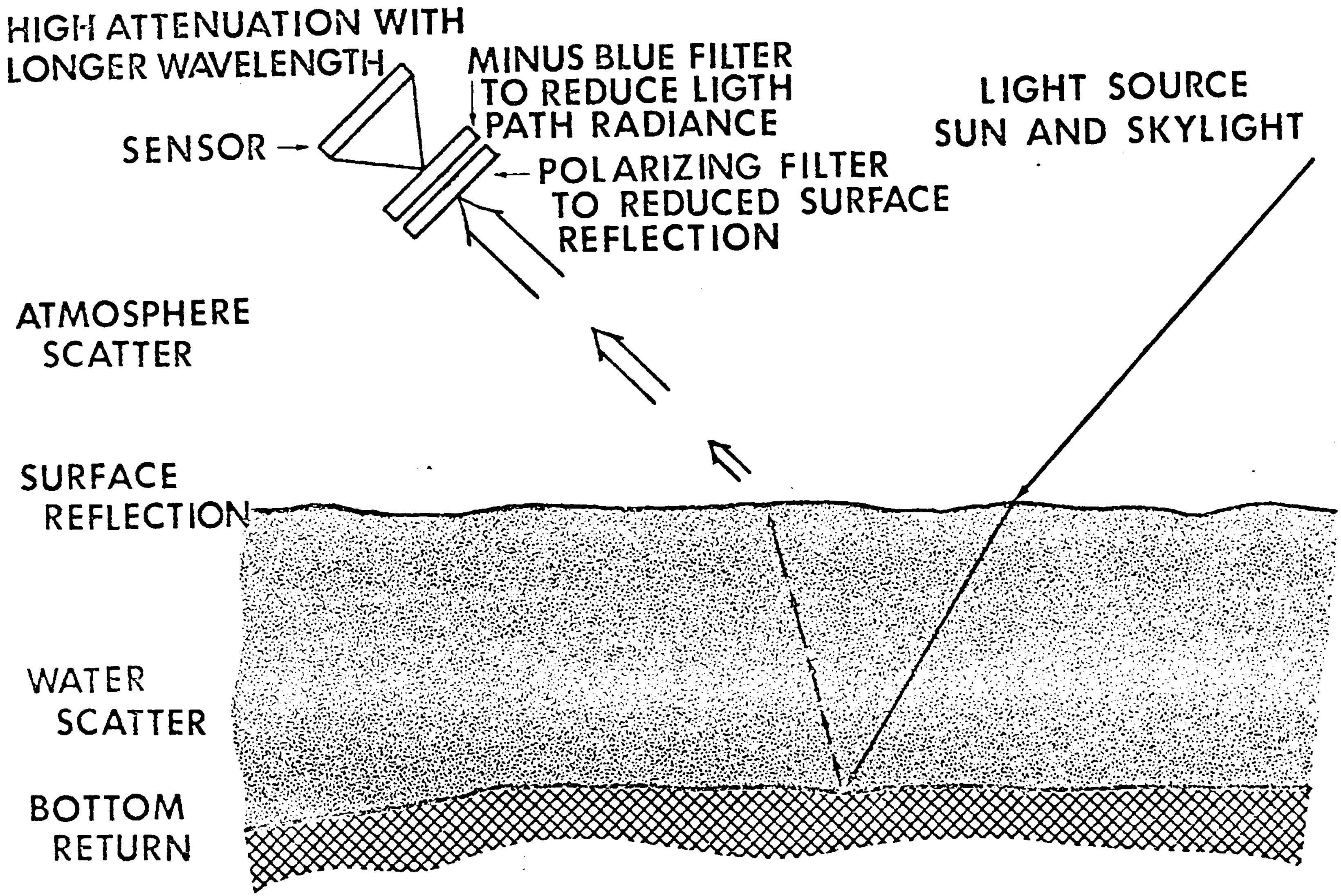

Figure 2. Aerial Photographic Monitoring of Water Quality

water depth or a change in water characteristics. Hence it is generally not feasible to relate scattered light intensity to water depth in a turbid nearshore area. As the water attenuation rate is a function of the wavelength of light, the bottom return can generally be eliminated by using the longer wavelength of bands, however, restricting the sensors to a limited region of the spectrum. Sensors that operate in the longer wavelength regions of the electromagnetic spectrum (greater than 700 nm) detect only surface characteristics which may or may not be representative of the water column. On the other end of the spectrum, high atmospheric attenuation in the ultraviolet region limit the utility of the spectrum below 400 nm. In general, sensors utilizing scattered solar energy for water quality applications will be limited to the visible and near visible regions of the spectrum.

AERIAL PHOTOGRAPHY

Since most people are familiar with photography, some information can be obtained with little special skill in analyzing the photography. In general, aerial photography will find its greatest utility in water quality studies by supplementing conventional surveys. General considerations of aerial photography for water quality studies are listed in the following sections.

SYNOPTIC OVERVIEW FROM ELEVATED VANTAGE POINT

From a boat an observer's view is restricted to surface features and subsurface features only within the immediate area, whereas from the air the field of view is increased and it is possible to detect critical features or conditions several miles away.

SPATIAL RESOLUTION

Spatial resolution indicates the size of the smallest image that can be identified. The unaided human eye can resolve about 5 lines per millimeter while modern photography can resolve several hundred lines per millimeter. Many small objects that would be invisible to the human eye can be recorded by photography.

SPECTRAL RANGE AND RESOLUTION

Film and filter combinations for aerial cameras extend the utility of aerial photography. Human vision is limited and the eye is sensitive to light with a wavelength extending from about 400 nanometers (deep blue) to about 700 nanometers (deep red). The photographic region is about twice this range. Special film filter combinations allow the recording of very narrow bands of light within the photographic region and permit the elimination of unwanted light thereby increasing the contrast between subject areas.

Aerial photography is not limited to determination of size and position of objects as in normal photogrammetry but can also be used as an energy sensor. The amount of light reflected from the water surface or water column is recorded by the film as film density and can be quantitatively measured with a photo densitometer. The composition of the reflected light can be determined by several film filter combinations such as color film or multiband camera system.

INSTANTANEOUS AND PERMANENT RECORD

Aerial photography will provide an instantaneous record of a dynamic system and a permanent record.

METRIC QUALITIES

Precise geometry of aerial photography permits accurate determination of size, shape and position of objects. Vertical photography of a water body will yield photos of constant scale. Linear measurements made on the photos can be converted to horizontal ground distances by simply multiplying by a scale factor (flying height divided by the focal length).

Sunlight reflection from the water surface is often a problem. This can be overcome by taking oblique photos. In addition, oblique photography permits the use of polarizing filters to reduce any light reflection from the water surface.

TURBIDITY

The term turbid is applied to waters containing suspended matter that interferes with the passage of light through the water. The turbidity may be caused by a wide variety of suspended inorganic and organic suspended materials ranging in size from colloidal to coarse dispersions.

Turbidity is an optical property of water which causes lightrays to be scattered and absorbed rather than transmitted in a straight line. The intensity of scattered light at right angles to the incident light is often employed to measure turbidity. The standard unit of turbidity was selected as one milligram of pure silica per liter. The Jackson turbidimeter is the standard instrument for measuring turbidity; however, photoelectric turbidimeters such as the nephelometer are employed in actual practice.

Since light scatter depends on the size and type of particles in the water, any comparison between turbidity and suspended solids must be restricted to the same material. Even in this situation there may not be a linear relationship between mg/l of suspended matter and turbidity units. For example a natural sample that shows a turbidity of 500 units when diluted to 5 to 1 with distilled water often shows a turbidity substantially

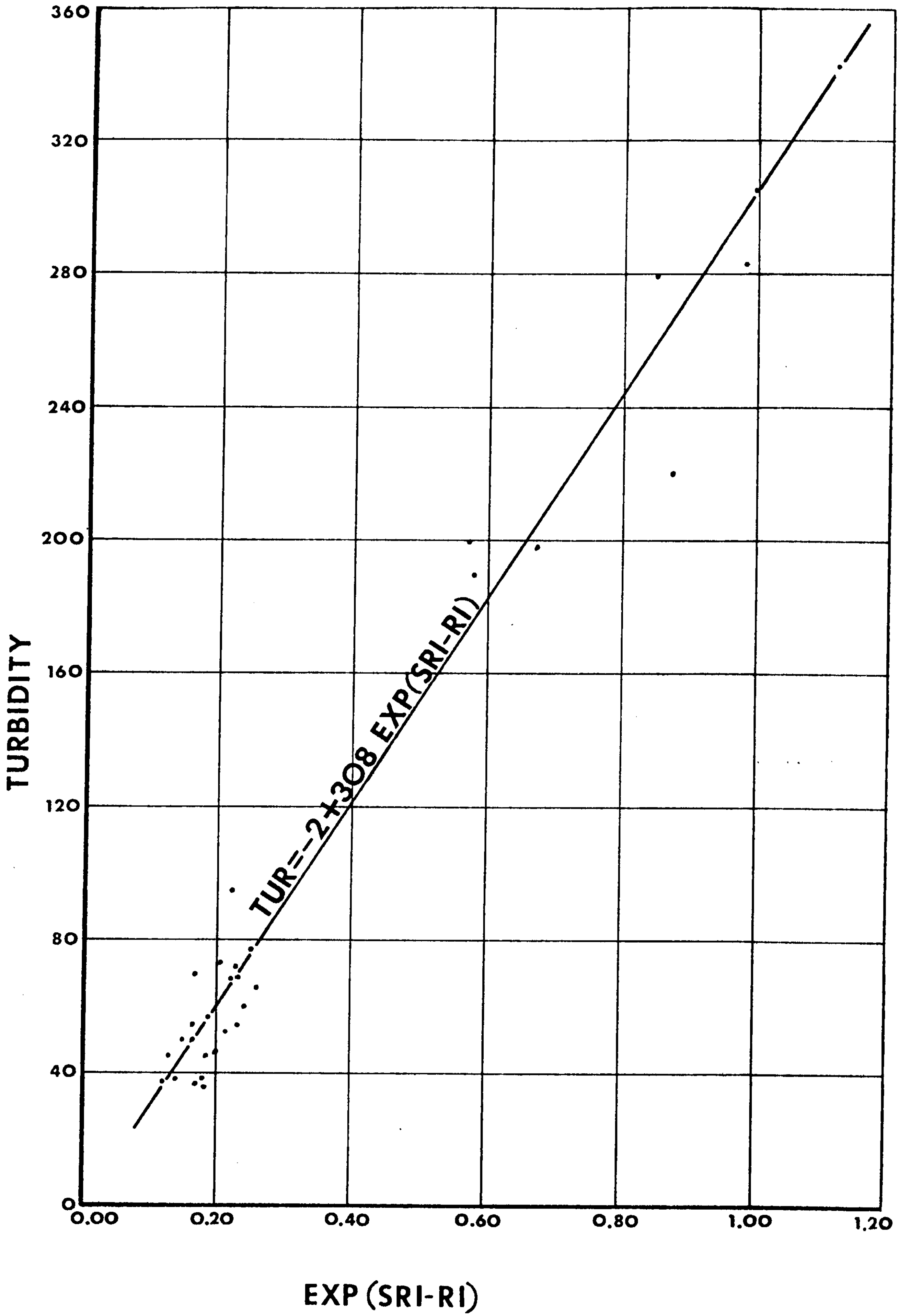

Figure 3. Plot of High Range of Turbidities and Red Band Film Densities for Color Infrared Film

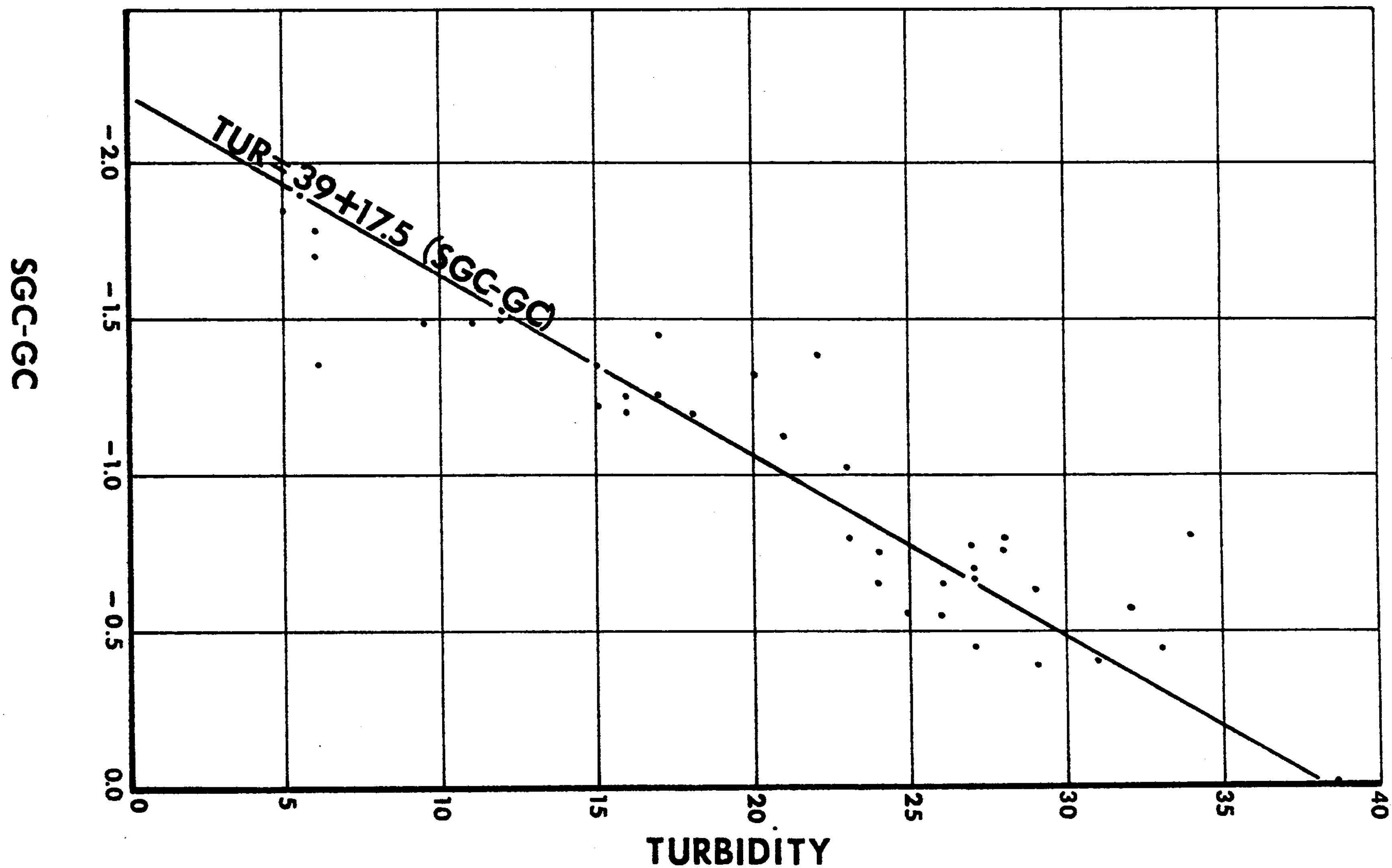

Figure 4. Plot of Low Range of Turbidities and Green Band Film Densities for Color Film

more than 100 units due to the quenching effect of light at high concentrations. In general there is no direct relationship between turbidity and the quantity of suspended matter in the water.

TURBIDITY STUDY

In 1973 we conducted a turbidity study of six ponds in the vicinity of Texas A&M University. On 12 different days and under various lighting conditions, airphotos were taken of the ponds. Three handheld, 35 mm cameras were used to take photos using three types of films. The films were color, color infrared and black and white. At the time of photography, triplicate water samples were collected from each pond and turbidity readings made. During the study turbidity values ranged from 4 JTU's to 340 JTU's. The range in turbidity was too great to use a single exposure setting for all the ponds. Since turbidity is a scattered light intensity measurement, each roll of film used in the study was standardized on the ground with a photograph of a standard 18 percent reflectance gray and taken outdoors prior to and after each flight. This procedure was used to compensate for variations in incident light, relative sun angle and film processing.

This study demonstrated that a valid relationship exists between film density and turbidity measurement and that a high degree of confidence can be placed on the results. The correlation coefficient between the observed turbidity values and the photographically derived expression EXP (SRI-RI) was 0.97 for 32 observations. SRI and RI are the red film densities as measured with a photo densitometer of the gray card and the pond, respectively, using color infrared film (Fig. 3). Figure 4 is a plot of the low-range turbidity measurements VS SGC-6C, where SGC and GC are the green film densities from color film of the standard gray card and the pond respectively. In this study the color film was overexposed for the high turbidity ponds and the color infrared film was underexposed for the low turbidity ponds. The correlation coefficient for the low range was 0.94 for 40 observations. The following recommendations were advanced by the study:

1. Take oblique rather than vertical photos.
2. To reduce the effect of atmospheric variations, take all photography from a flow altitude such as 500 ft.
3. Sun altitude should be between 30 and 60 degrees above horizon.
4. Use several photographic exposures to insure proper exposure.
5. There was no significant difference among color, color infrared, and filtered black and white films.
6. Film density readings should only be taken near the center of each photo to eliminate camera lens fall off.
7. The angle between the incident sunlight, gray card and camera, and the incident sunlight, pond and camera should be the same and should be held constant.

EVALUATING TURBIDITY PLUMES

Using aerial photography, plots of a turbidity plume can be drawn showing lines of equal turbidity (150 isoturbidity plots). In evaluating these plots care must be taken not to assume a fixed relationship between suspended solids and turbidity. As the water mass moves away from the source of the suspended material, large particles will settle out of the water column and the particle size distribution of the suspended material will vary thus changing the relationship between turbidity and suspended solids. After the layer particles have settled out and only colloidal and extremely fine dispersions remain, turbidity can be used to estimate dilution factors.

The primary factors influencing the fate of the colloidal suspension are: water currents, wind, density stratification and diffusion coefficients. Water currents can be measured from in situ current meters or aerial photography of dye markers and diffusion coefficients estimated from the turbidity plots or dye markers.

SUMMARY

Aerial monitoring can be used to study not only objects, but also processes. Mixing and circulation patterns in lakes and coastal waters can often be observed by the natural variation in turbidity of the water. The effluent plume from coastal streams can be studied to obtain a better understanding of the dispersion process and longshore currents. Dye drops from an aircraft can be used to compute water currents and diffusion coefficients.

Experience has shown that a 35 mm, handheld camera taking oblique photos from a 500-ft altitude can be used to give reliable turbidity values in water. This procedure can be used to quantitatively evaluate turbidity planes for dredging operations or natural sources. Aerial photography has an advantage over conventional sampling in that it provides an elevated vantage point. It provides an easy method for determining the relative impact of dredging activity by comparison plumes with man-generated turbidity plumes.

HYDROLOGIC AND SEDIMENTOLOGIC STUDY OF THE OFFSHORE DREDGE DISPOSAL AREA, SAVANNAH, GEORGIA

by

George F. Oertel*

ABSTRACT

In 1973, 1.15 million m^3 of dredged material were deposited 13.0 to 16.0 kilometers seaward of the Savannah River entrance. The disposal produced a 0.75 m average increase in bottom elevation in a predetermined area. In the southeastern portion of the disposal area the dredged material formed a mound composed of 30 percent coarse sand which extended 6 m above the bottom to a depth of minus 9 m (MLW). The coarse sand accumulated in the area directly below the disposal path of the hopper dredge. Fine-grained dredged material was dispersed by coastal and tidal currents away from the disposal path of the dredge. The percentage of fine and very fine sand increased to over 90 percent in the deeper water around the mound. More bioturbation (biologic mixing of sediment) was apparent in the fine-grained than in the coarse-grained material.

The stability of the sediment in the disposal area was closely related to water depth and physical energy. Near-bottom currents were generally too weak (less than 12 cm/s) to rework dredged material once it was deposited. The upper portions of the mound were most susceptible to change because of their proximity to wave surge and stronger currents (up to 30 cm/s). During storms the combination of wave and surface currents had the greatest effect upon the movement of the mound. During a northeast storm season in 1973 (September through November) the mound became asym-

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metrical and migrated approximately 0.54 kilometers in a southerly direction. During the low energy portions of the years, the mound was relatively stable and surface creep of sediment produced minor bedform changes on the seabed.

INTRODUCTION

The growth of oceanic shipping has resulted in increasing demands on many harbors and port facilities in industrial areas. As shipping traffic and the size of ships has increased, it has become necessary to expand channel width and depths. Finding sites to dispose of dredged materials often presents problems.

Harbor-dredged materials are generally disposed of in landfill areas on the banks of the waterway. However, in highly industrial and urbanized areas there is little room remaining for fill areas, and to avoid environmental problems many industries have utilized offshore disposal areas. Approximately two-thirds of all dredged material is now disposed of in open water (Boyd et al., 1972).

Seaward of harbor entrances hopper dredges are commonly used. Material is pumped into the hull of the ship until a number of large bins or hoppers are filled. The ship then transports the material to a predetermined dump site and sediment is released into the water producing a plume in the path of the ship.

Numerous ecological pressures in nearshore and estuarine areas have influenced private, public and commercial enterprises to consider offshore areas for disposal of dredged material. In 1972, more than 112 sites were used for offshore disposal of waste and dredged material (Edge and Dysart, 1972).

The ocean environment is subject to complicated energy forces which may vary from hour to hour. Wind, tidal and wave forces all exert significant and variable influences on suspended and bedload transport. Wind primarily influences the upper portions of a water column but in shallow areas this influence may extend to the bottom. While wave currents influence the bottom in shallow water, the characteristics of waves are variable. Those with long periods often produce foreshore accretion while short period waves produce foreshore erosion. Reversing tidal currents, geostrophic and other density-related currents may also influence water-mass movements and sedimentation. The interaction between these forces creates a complicated physical environment influencing the fate of material dumped at offshore sites. To design, implement and manage a sound disposal program, a better understanding is needed of this complicated situation and the hydrodynamic phenomena influencing it.

The Savannah District of the U.S. Corps of Engineers utilizes an ocean dump site located approximately 13.0 to 16.0 kilometers seaward and southeast of the Savannah River entrance (Fig. 1). This site has been used to dispose of spoil from hopper dredges since about 1964. The site is located on an old submarine ridge which is clearly indicated on older (1939) Coast and Geodetic survey charts (No. 1241). In December 1972, the Savannah District of the Corps of Engineers let Contract No. DACW21-73-C-0004 to study the hopper dredge spoil disposal area. Textural, topographic and hydrologic surveys of the site were made before, during and after the hopper dredge "Geothals" dumped approximately 1.15 million m^3 of sand in the area.

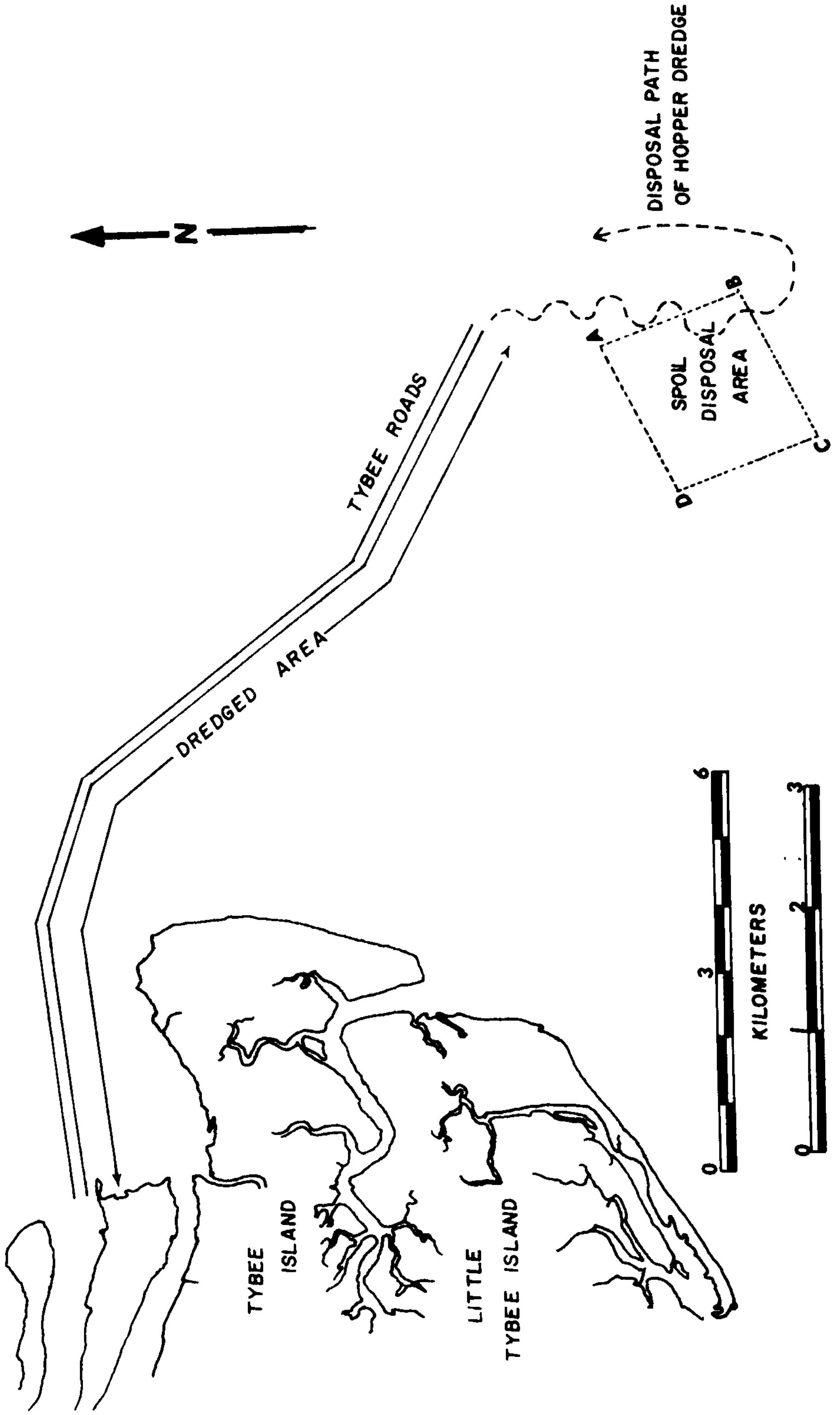

Figure 1. Location map of dredged material disposal area illustrating the path of the hopper dredge during disposal

BOTTOM TOPOGRAPHY

Topographic analyses of the ocean disposal area at the Savannah River entrance were made using direct SCUBA observation, fathometer profiling and engineering surveys conducted by U.S. Army Corps of Engineers. Initial observations illustrated that the disposal area was above a mound of material composed of two sub-parallel, longitudinal ridges. The outer ridge transected the southern corner of the area and showed the greatest relief (approximately 5-6 m). The stoss slope of the ridge faces almost due north. The inner ridge had approximately 1.5-2.5 m of relief.

SMALL-SCALE TOPOGRAPHY

SCUBA observations (30 July 1973) adjacent to the ridges indicated a variety of small bedforms and surface features. On the crest of the ridge the undulating bottom was composed of small-scale linguoidal ripples. The sediment on the bottom was relatively stable because a film of brown algae cemented many of the grains into a thin crust. Although measurements were not made of the physical characteristics of the water, an obvious thermocline existed approximately 5 m below the water surface. There was a relatively weak current above and a relatively strong current below the thermocline. Observations of the seabed indicated that no sediment movement was occurring during the reconnaissance. Swell conditions prior to and during the dive were minimal with a wave height of approximately 0.3-0.5 m and a wave period of approximately 4.3 seconds. The swell conditions prior to and during a second dive in August 1973 produced wave heights of 0.3-1.0 m and the periods were often greater than 8 seconds. The small-scale bedforms reflected differences due to wave heights. Longitudinal megaripples with amplitudes of approximately 8 centimeters and wavelengths of approximately 40 centimeters were present along the crest of the ridge. The grain sizes of particles in these dunes were larger than those observed on 30 July 1973. The megaripples were generally composed of medium to coarse sand with numerous shell fragments. Aggregate pebbles of sandstone cemented by a brown algal matrix were also observed on the seabed. Since the wave crests were essentially parallel to the crests of the megaripples it was assumed that the longitudinal megaripples were a direct response to the large swells that were "touching" bottom on the crest of the ridge. Linguoidal megaripples were present on the steeper face of the ridge. At the base of the ridge a complicated pattern of longitudinal ripples was superimposed upon a relict surface of cuspate ripples (possibly from an earlier storm). The amplitude of these ripples was 2-4 centimeters and the wavelength was approximately 15-20 centimeters. The low relief of these bedforms illustrates the diminutive effect of sea swell on sediment movement at the base of the ridge.

On 3 October 1973, the sea swell was 0.5 to 0.8 m and the wave periods varied between 6 and 12 seconds. Flat-topped, longitudinal ripples oriented along a 40° bearing (approximately the same bearing as the crests of the sea swell) were present along the crest of the ridge.

LARGE-SCALE TOPOGRAPHY

Topographic surveys were also made before and after the 1973 dredged material disposal operation at the dump site. A prominent east-west trending ridge transected the southeast corner and a less prominent northeast-southwest trending ridge transected the central portion of the disposal area. Surveys taken in December 1972 and February 1973 illustrated very little change in the bottom topography. In October, November and December 1973, maintenance dredging was conducted at the seaward portion of the

Savannah River entrance and 1.15 million m^3 of sediment were dumped at the disposal area. In February 1974, another topographic survey showed that drastic changes had occurred in bottom topography. A relatively large mound was present in the east-central portion of the dump area, and the double ridges that were present earlier were missing. This led to the conclusion that the inner ridge had been leveled and that the outer ridge formed the mound in the east-central portion of the disposal area. Profiles from precision bottom soundings later indicated this had not been the case. The two ridges had moved in a southerly direction out of the disposal area (Figs. 2a, b). The displacement of these ridges was caused by the force of complicated patterns of tidal, wave and seasonal coastal currents. The large ridge (4 meters relief) contained a volume of approximately 0.85 million m^3 of material. During 1973-1974 0.85 million m^3 were removed by the shifting of a bedform crest and 0.91 million m^3 were added by the trough filling in the lee of the crest. Thus between 1973 and 1974 approximately 61,000 m^3 of sediment moved into the spoil area by natural means (Table 1).

Prior to the 1973 spoil disposal operation (February 1973) the volume of the spoil area above a datum elevation of minus 13 m, was approximately 11.798 million m^3. Following the disposal operation (March 1974) the total volume of the disposal area above the same elevation was 13.045 million m^3. Of the 1.246 million m^3 gained, 0.06 million m^3 have moved into the area by natural means (as illustrated above). The remaining 1.185 million m^3 need to be accounted for. During the 1973 dredging period the hopper dredge "Goethals" dumped approximately 1.1 million m^3 of sediment in the area. This accounted for 97 percent of the mass gained in 1974. A new topographic high (mound) that appeared in the center of the disposal area

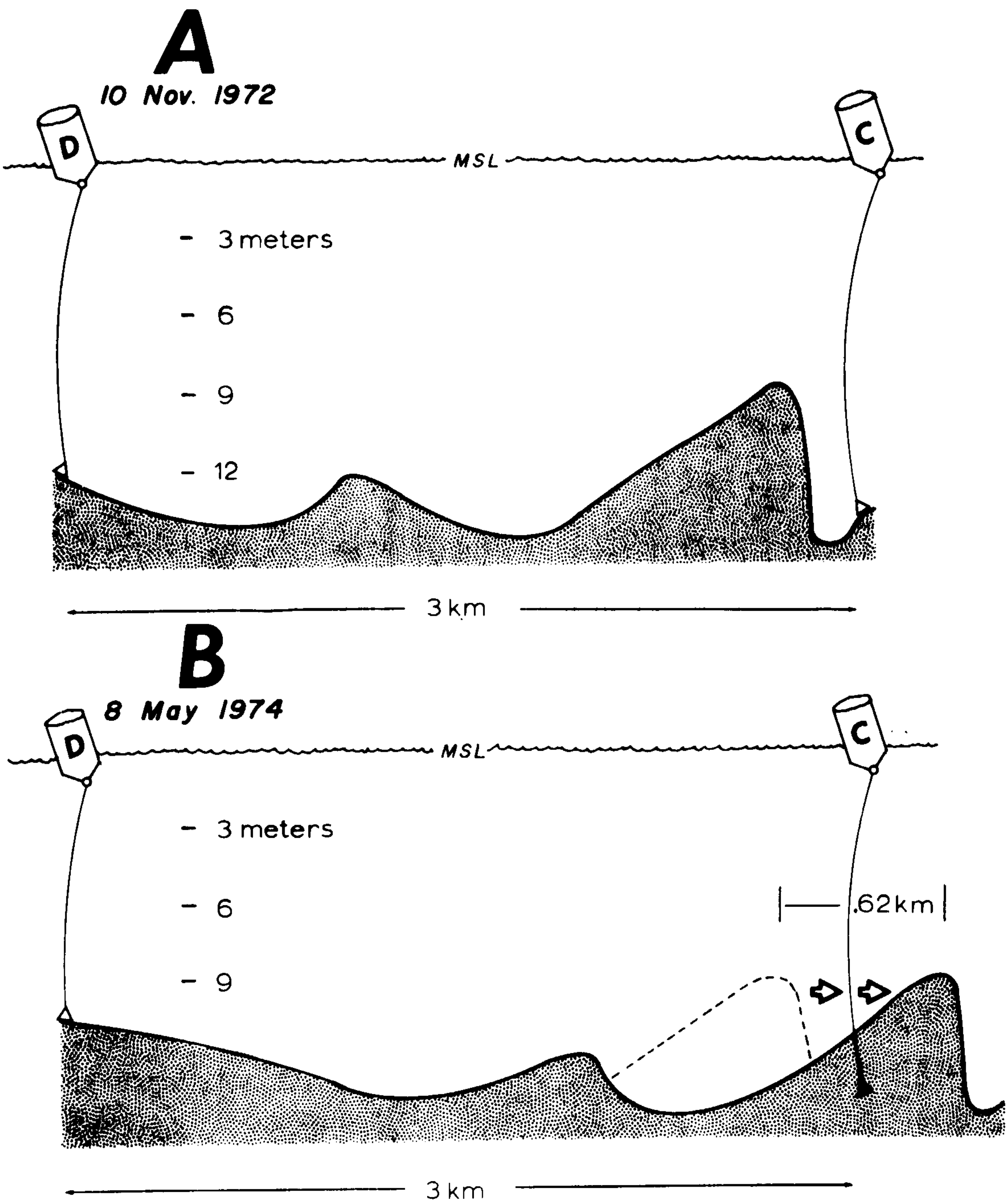

Figure 2 a. Profile of precision bottom soundings between buoys D and C, 10 November 1972 (Prior to 1973 disposal operation).

b. Profile of precision bottom soundings between buoys D and C, 8 May 1974 (Following 1973 disposal operation).

contained approximately 29 percent of the new material. The mound was predominantly composed of coarse and medium sand and was approximately 1.2 m higher than the 1973 elevation. The remaining 71 percent of the spoil material is equally distributed about the disposal area and had produced an average increase of approximately 0.75 m above the 1973 elevations.

SEDIMENTARY CHARACTERISTICS DURING DISPOSAL OPERATION

Between September and December 1973, 1.1 million m^3 of dredged material was deposited within the limits of the material disposal area. Sediments were sampled in this area before, during and after the disposal operation. A small box corer was used to take samples and relief peels and x-ray radiographs were made to analyze the sediments. Qualitative and quantitative analysis was made of grain size, texture and biogenic and physical structures. The spatial distributions of these data were plotted on base maps of the respective sample grids.

The distribution of coarse sand was related to submarine topography. Concentrations varied from 0 to 40 percent and high concentrations (greater than 20 percent) were generally associated with topographic highs. Before the 1973 disposal operation the coarse sand was associated with the east-west trending ridge in the southern corner of the disposal area. Isolated patches having concentrations greater than 20 percent were also present on several small topographic highs. Low concentrations were generally located in the northwest portion of the disposal area. SCUBA observations indicated that the coarse material contained broken shells, quartz sand and shark teeth that were stained black.

During the dredging operation the distribution of coarse sand was similar in a number of ways to the distribution before the dredging commenced.

These areas conformed to the disposal track of the hopper dredge (Fig. 1). Following disposal low concentrations of coarse sand were found in the northwest and southwest sections (Fig. 3). The area encompassing the 20 percent contour for the during and after surveys was approximately 4 to 5 times larger than before the dump. That encompassing the 30 percent contour also progressively increased in size. Concentrations of fine and very fine sand were generally high in topographic lows where the coarse sand concentrations were low. The concentration of coarse sand increased in the southeast corner of the disposal area at the expense of the concentration of fine and medium sand (Figs. 4 and 5). During the disposal operation concentrations of fine and very fine sand fraction ranged from 50 to 90 percent of the sediment. After dredging fine and very fine sand concentrations ranged from 30 to 90 percent of the sediment.

Samples in the disposal area contained between 0 and 4 percent silt and clay (Fig. 6). The northwest portion contained more than 3 percent silt and mud. The before and during surveys showed similar patterns with higher concentrations in the northwest and lower concentrations (1%) in the south and southeast part of the disposal area. Isolated high concentrations also appeared in the southern portion of the disposal area. The after survey illustrated similar concentrations and trends though a slight decrease in silt and mud in the central and a slight increase in the northwest portion of the area was apparent.

Biological activities as indicated by bioturbation were generally related to the distribution of silt and clay (Figs. 6 and 7). Sediment that was 80 to 100 percent bioturbated was located in the north and northwest part of the disposal area (Fig. 7). At the time of the "before survey," sediment that was 10 to 40 percent bioturbated was located in the south and

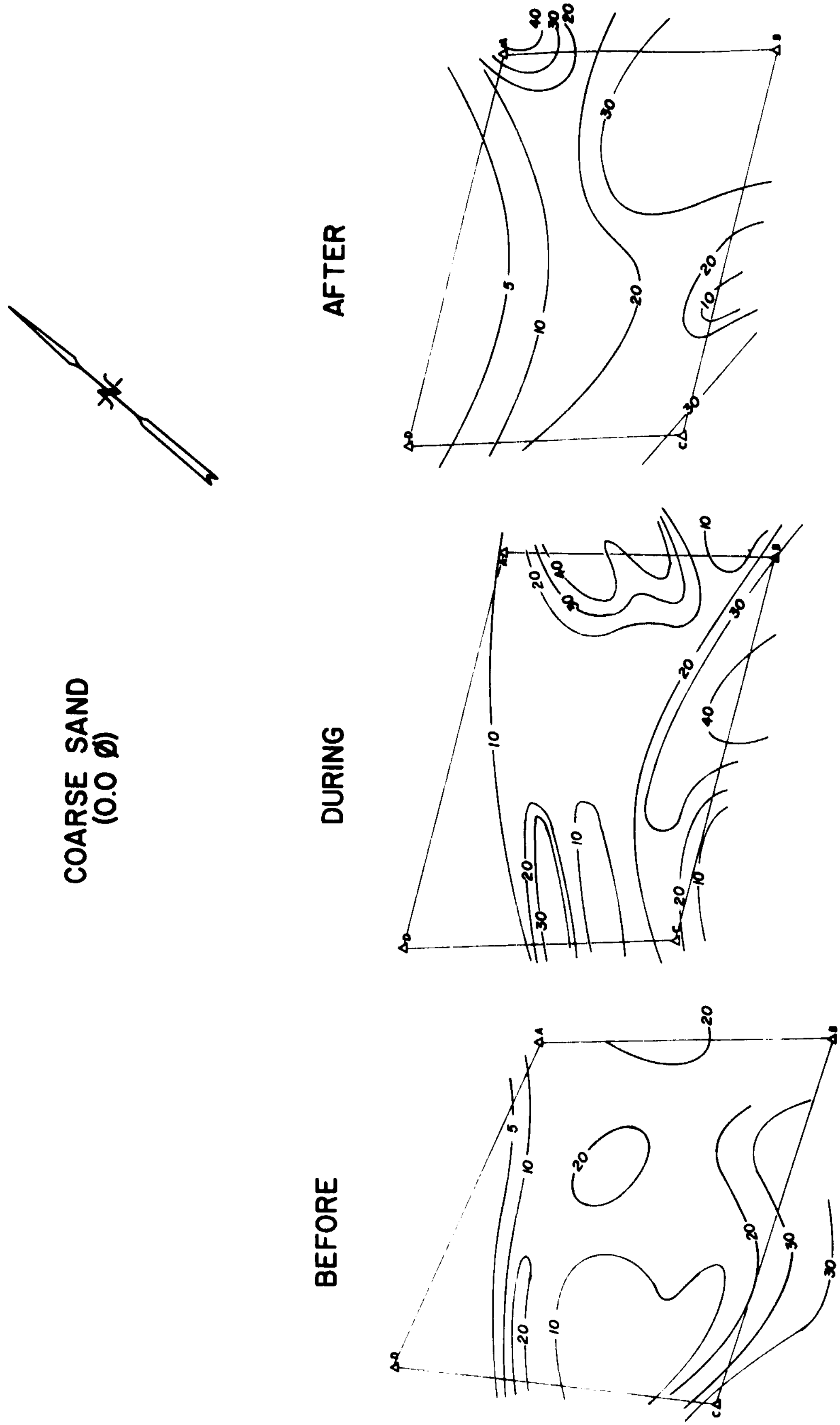

Figure 3. Maps of the dredged material disposal area illustrating the concentration and distribution of coarse sand before, during and after the 1973 disposal operation. Contours indicate the percentage of coarse sand in samples.

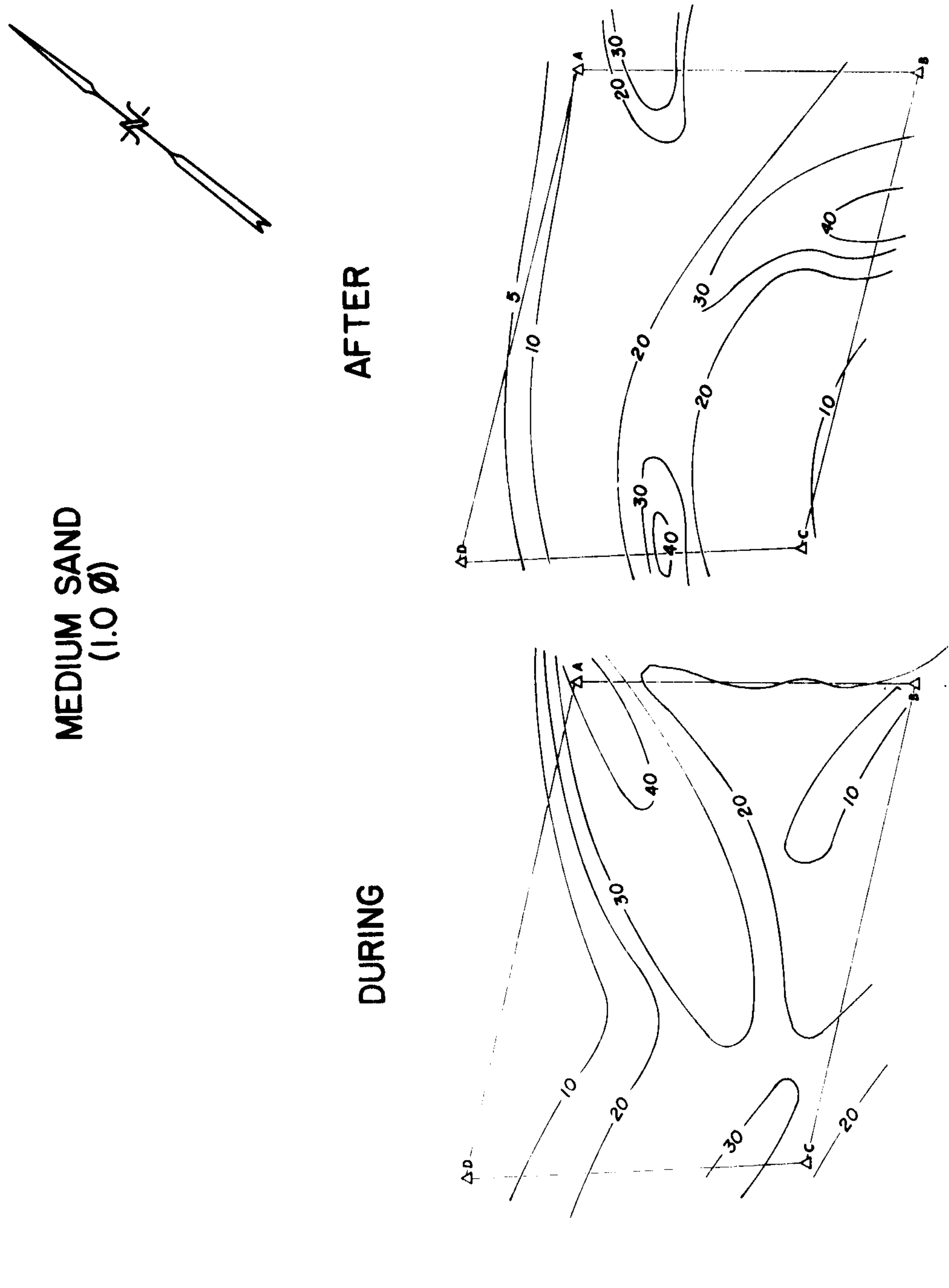

Figure 4. Maps of the dredged material disposal area illustrating the concentration and distribution of medium sand before, during and after the 1973 disposal operation. Contours indicate the percentage of medium sand in samples.

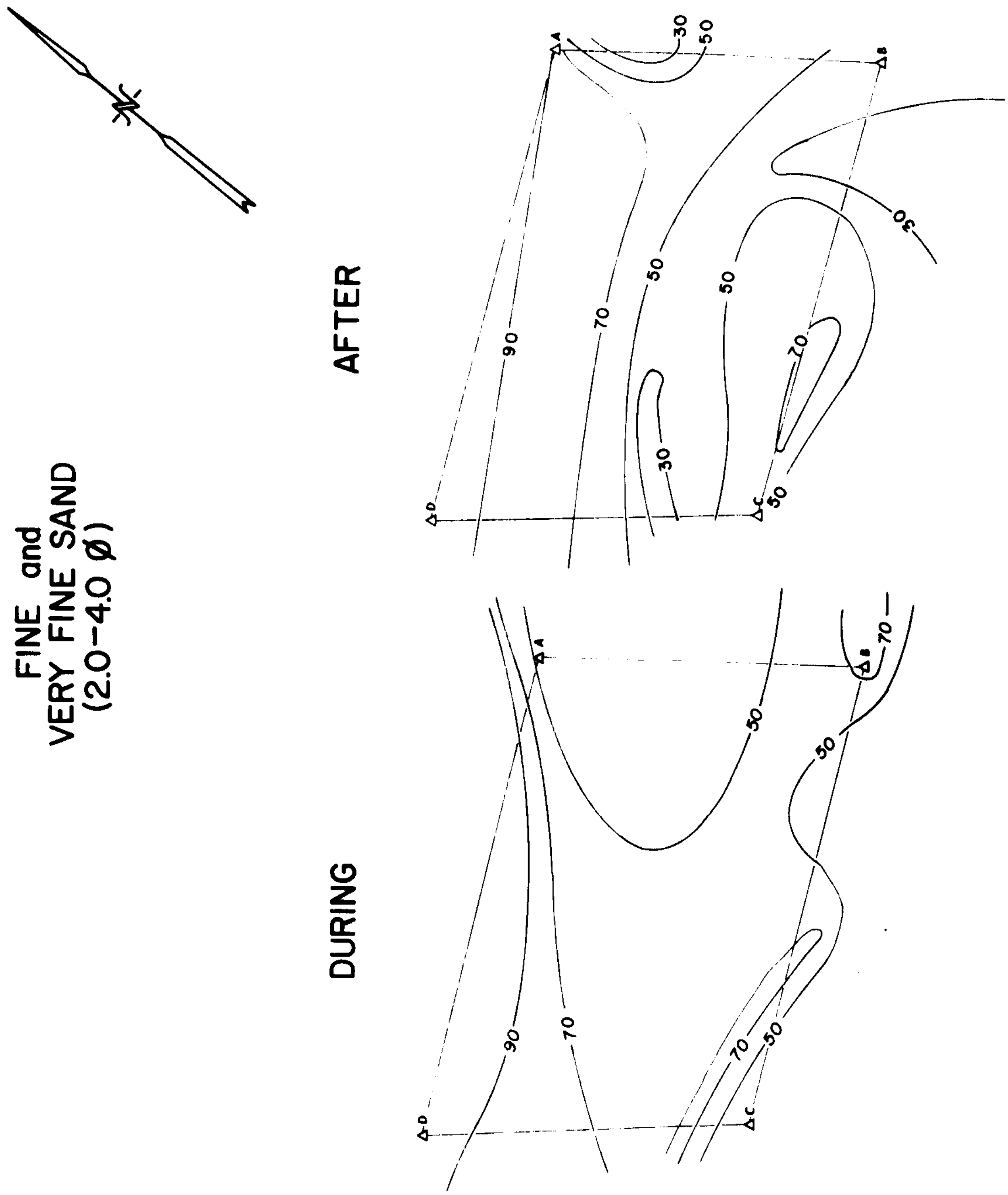

Figure 5. Maps of the dredged material disposal area illustrating the concentration and distribution of fine and very fine sand before, during and after the 1973 disposal operation. Contours indicate the percentage of fine and very fine sand in samples.

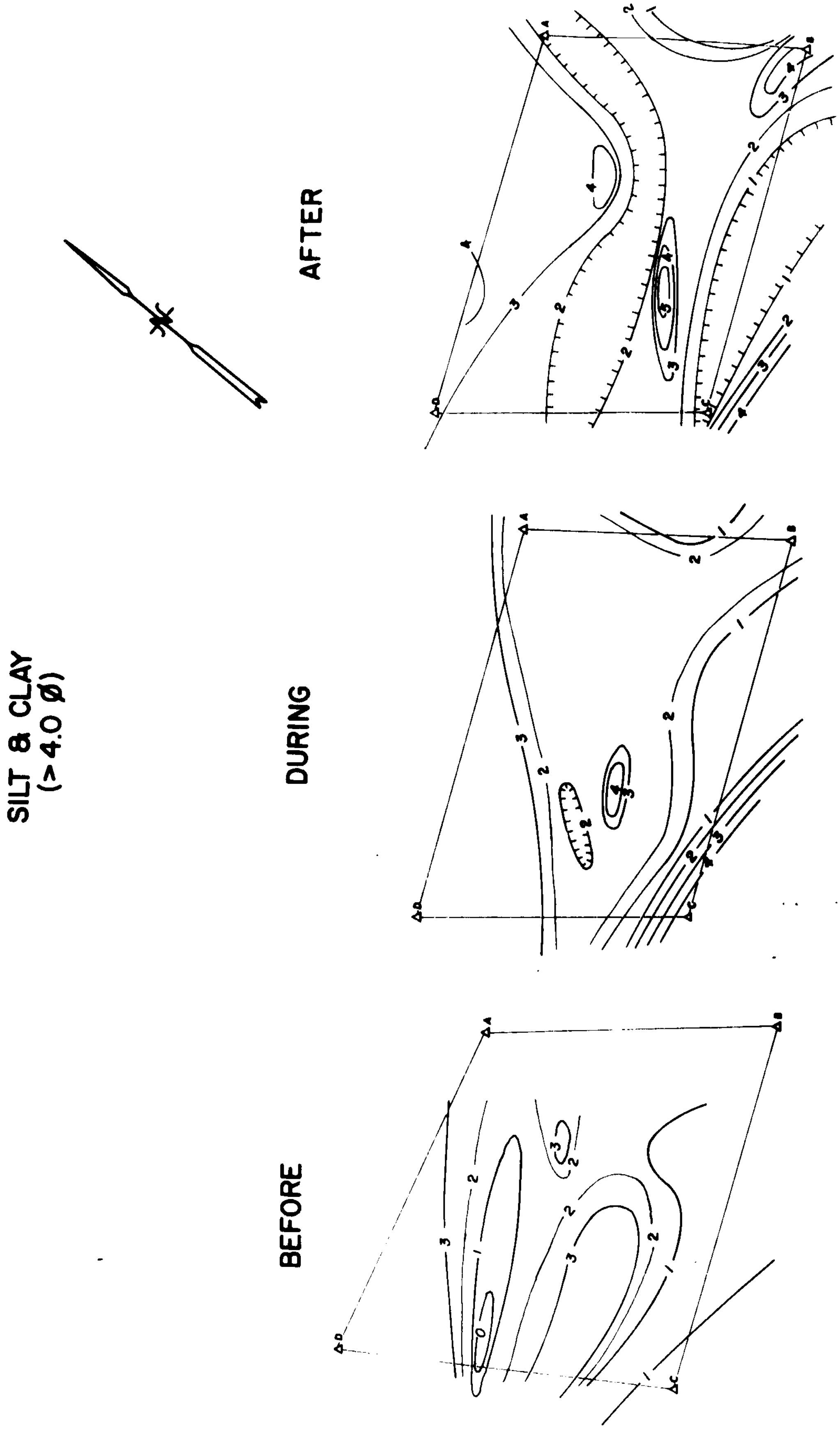

Figure 6. Maps of the dredged material disposal area illustrating the concentration and distribution of silt and clay before, during and after the 1973 disposal operation. Contours indicate the percentage of silt and clay in samples.

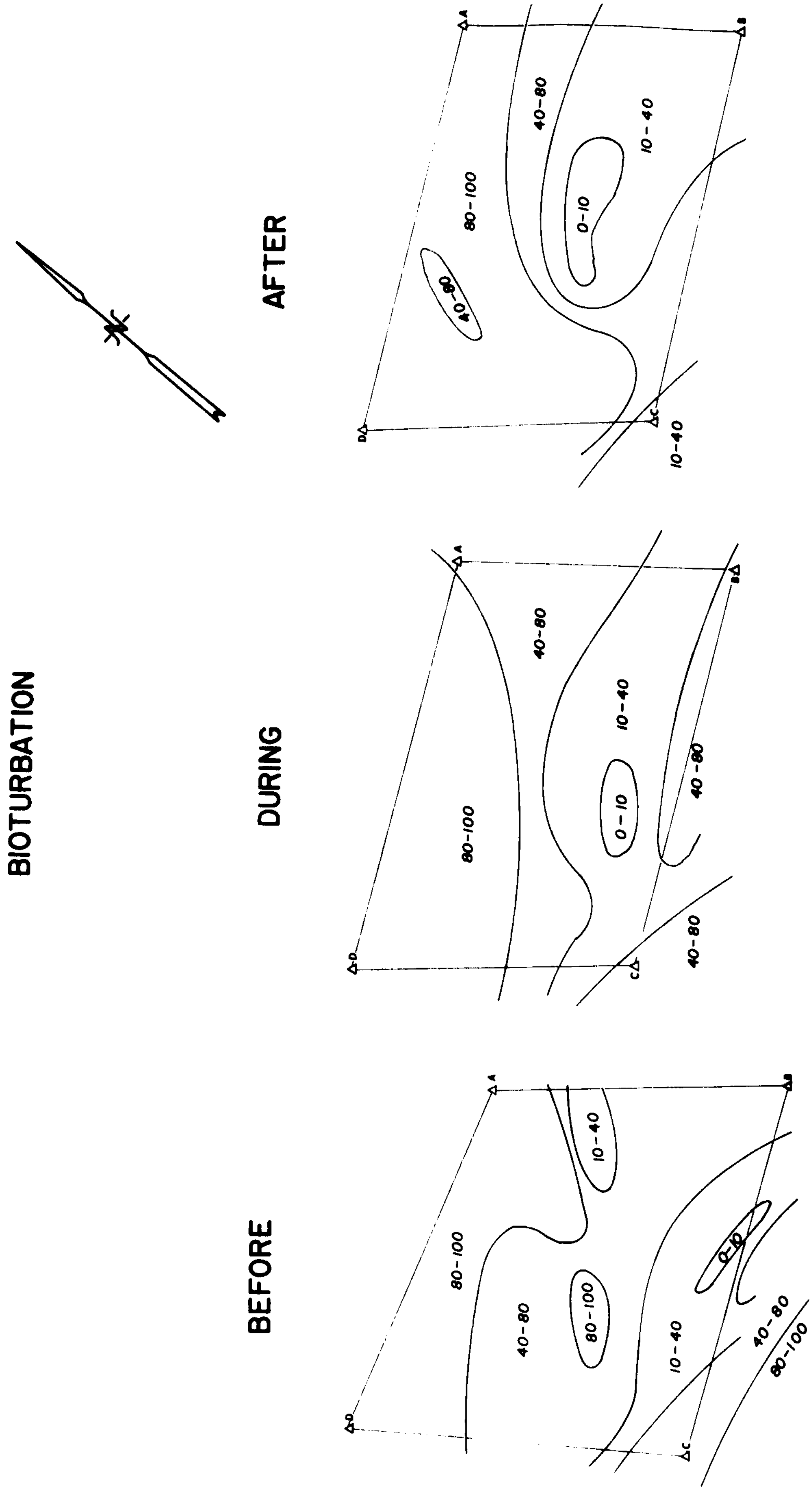

Figure 7. Maps of the dredged material disposal area illustrating the degree and distribution of biologically-mixed sediments. Contours indicate the percentage of a sample which does not illustrate sedimentary structures produced by physical processes.

central portions of the area. The "during survey" illustrated two 10 to 40 percent bioturbated zones (one in the central-east part and one the southern corner) merging at the southern corner of the area. After disposal the two 10 to 40 percent zones were separated, the southern part moving almost entirely out of the disposal area and the central part moving easterly. The area greater than 40 percent bioturbated was essentially the same for the before and after survey, however, during disposal a decrease occurred in the area occupied by the sediments that were more than 40 percent bioturbated.

HYDROLOGIC SURVEYS AND FLOW DYNAMICS

Wave and tidal currents are the principal forces affecting sediments at the dredged material disposal area, however, it is difficult to distinguish the relative fraction of the total velocity field produced by each. In this study, differentiation of the component forces is not critical since the total resulting force is what ultimately affects sediment transport. Between May and October 1973 over 3600 current data points of speed and direction were collected in the water above the dredged material dump. In general, all data illustrated semidiurnal reverses in tidal flow (Fig. 8). During the ebb, the direction of flow offshore was toward the east between 100 and 136°. During the flood, the direction of onshore flow was toward the west-northwest between 282 and 323°. The average speed of water flowing one meter above the seabed was 13.5 cm/s (Table 2). This average speed was too weak to induce tracted sand transport on the seabed, however, occasionally current speeds were sufficient (20-30 cm/s) to produce some bedload transport and the formation of ripples and megaripples. The duration of these relatively high current speeds provides a rough approximation of relative sediment transport distances in different parts of the disposal

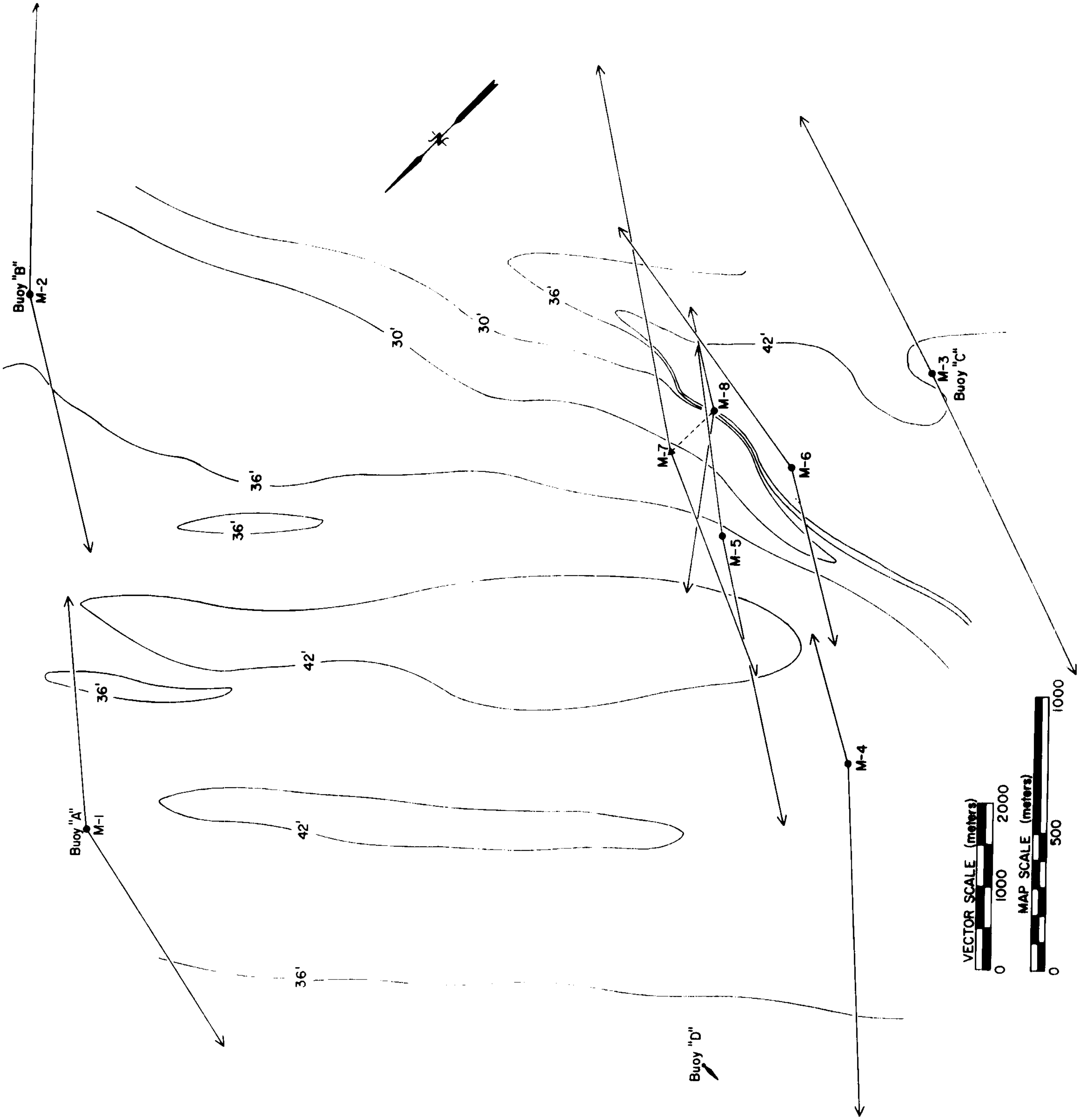

Figure 8. Topographic map of the dredged material disposal area illustrating duration/velocity vectors for ebb and flood portions of the tide. Flood vectors are toward the northwest and ebb vectors are toward the southeast.

area.

The product of the mean current velocity (meters/second) and the duration (seconds) is a vectoral approximation (meters) of the total amount of water flowing past given point. A graphic comparison is made by obtaining the product of the duration and speed in flood and ebb directions (Fig. 8). The product of the duration of speeds greater than 22 cm/s (in a given direction) and 22 cm/s yields a vectoral approximation of low to moderate sediment transport. The product of the duration of speeds greater than 30 cm/s (in a given direction) and 30 cm/s yields a vectoral approximation of moderate to high sediment transport. Vector summation for ebb and flood flow yields an approximation of residual flows for a semidiurnal cycle (Figs. 9 and 10). The residual flow of water is illustrated in Figure 9. The residual flow of currents greater than 22 cm/s is illustrated in Figure 10.

On the 7th and 8th of May, most of the water motion on the northeast side of the disposal area was in an onshore-offshore direction, however, the resultant flow for a 13-hour tidal cycle was toward the southwest.

On the 23rd and 24th of May water along the southwestern portion of the disposal area also had both flood and ebb motions, however, the resultant flows after the 13-hour tidal cycles were to the northwest at stations 4 and to the west-northwest at station 3.

On 27, 28 and 29 July 1973, current meters were placed landward (station 5) and seaward of a large sand ridge (station 6). The ebb and flood motion of tidal currents was again observed. The meter landward of the ridge illustrated a strong onshore component whereas the seaward-oriented meter illustrated a flow parallel to the ridge in an offshore direction.

The patterns of flow induced by the sand ridge were also determined

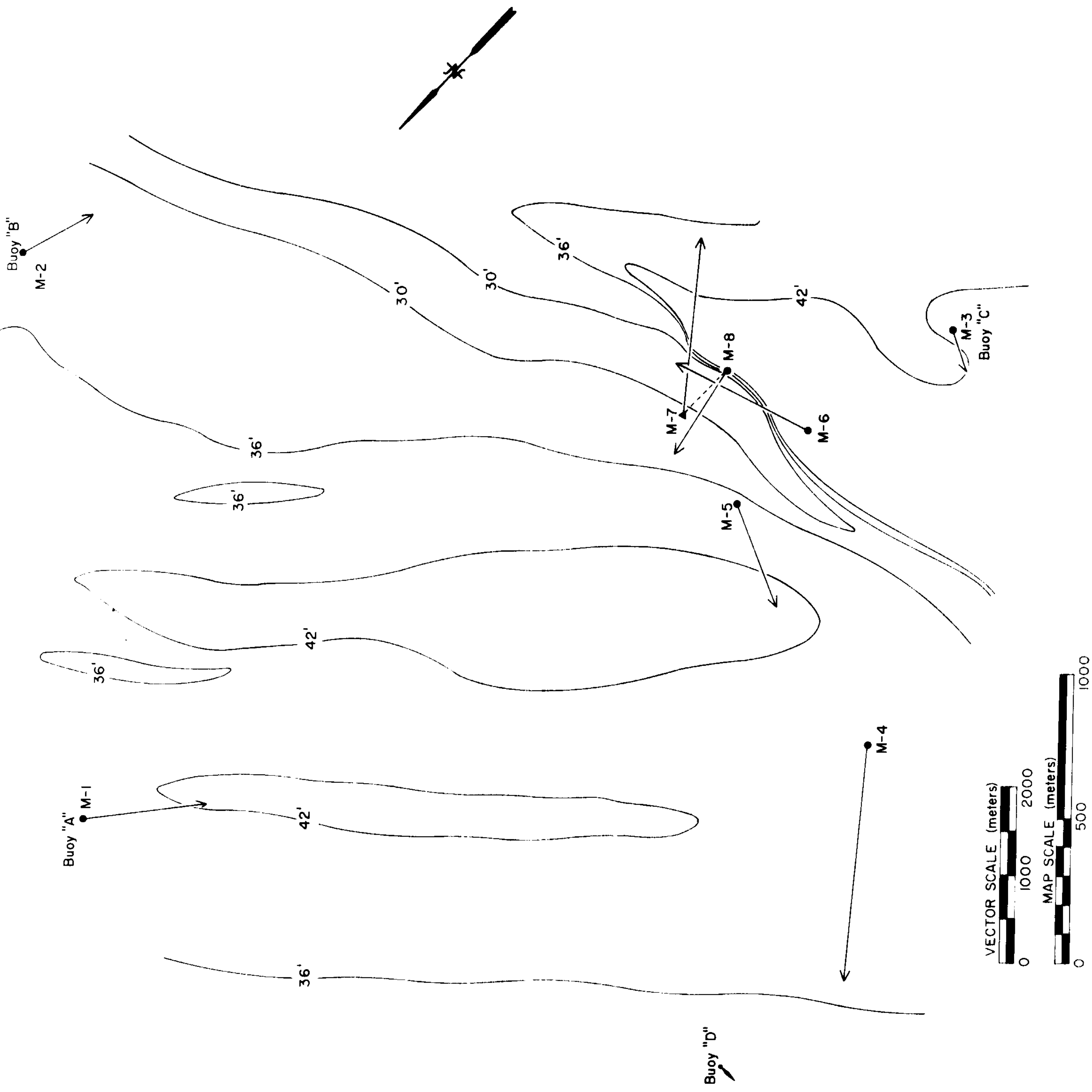

Figure 9. Residual flow of water at respective stations based upon vector summation of average ebb and flood flow. The residual flow at stations M-1 and M-2 was approximately longshore and normal to ebb and flood currents. The base of the ridge (M-6 and M-8) residual flow was ridge normal on toward the steep slope of the ridge. At the crest of the ridge the flow was offshore.

Figure 10. Residual flow of water for velocities greater than 22 cm/s (an approximation of low to moderate sediment transport). Vectors indicate an onshore direction of flow.

by placing one meter at the base of the ridge (meter 8) and another 5 meters above it (meter 7) at the same level as the ridge crest. The upper meter illustrated a residual offshore- and the lower meter a residual onshore-flow. The flow near the bottom was generally very weak and was greatly influenced by bottom wave surges. In effect, the offshore flow coming off the top of the ridge and the onshore flow coming up the base of the ridge produced an "upwelling" along the seaward side of the ridge.

While the total velocity field reflects water movement only the higher velocities (greater than 22 cm/s and 30 cm/s) also illustrated the reversing flow of tidal currents. Generally, the residual flow determined by mean velocities was in the same direction as that for higher (22 cm/s and 30 cm/s) velocities. At two stations (2 and 7) the residual flow for mean velocities was offshore while that produced by currents able to transport sand (22 cm/s and 30 cm/s) was onshore.

Station 5, located approximately 0.4 kilometers landward of the crest, on the stoss side of the sand ridge, had the strongest residual onshore flows for currents greater than 22 cm/s and 30 cm/s. This suggests a residual transport of sediment away from the ridge crest during low-energy conditions.

CONCLUSIONS

Six months following the disposal of 1.1 million cubic meters of dredged material at the Savannah River ocean disposal area, all of the dredged material was still within the dump area. The dredged material disposal bank increased an average of 0.75 m with some areas measuring approximately 1.25 m.

Following dredged material disposal the grain sizes of the bottom sediment increased in the percentage of coarse sand, silt and clay fractions.

Currents at the disposal area were in onshore and offshore directions in periods corresponding to the semidiurnal flow of the tides. Minor bedform orientations reflected both sea swell and the bi-polar flow of the tidal currents. The calculated resultant movement of water after a 13-hour tidal exchange illustrated areal variability within the disposal area. The resultant vectors were onshore, offshore and longshore. High velocities capable of producing sediment transport formed residual currents oriented in onshore direction. Localized circulation created by ridges and mounds produced an "upwelling effect" along the seaward edge of these topographic highs.

Average daily conditions appeared insufficient to induce the transport of major quantities of sediment out of the disposal areas, however, several northeast storms were of sufficient magnitude to produce bedload transport at the minus 10 meter surface. Several large northeast storms were also of sufficient magnitude to displace the upper portion of a sand ridge approximately 0.48 kilometers across a minus 10 to minus 12 meter.

ACKNOWLEDGMENTS

The intrinsic nature of research in this study has required the assistance and cooperation of many persons. The research would not have been possible without the assistance of Captain Paul Glenn and the crew of the R.V. GOLDEN ISLES. Work in the field and laboratory was supported by numerous technicians including Matt Larsen, Sharon Greer, Steve Arpadi, Eric Knutdson, Brian Edward, Britt Holloway, Mark Chaffey, Steve Howie, Rick Brokaw, Jean-Pierre Hsu and Susan Erlenwein. Drafting for this report was done almost exclusively by Matt Larsen.

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TABLE 1. Dredged material dumping statistics for 1973 operation year.

BEFORE	
$Total_{(1)}$ (above seabed -13m)	11,798,400 cu m
Ridge (above seabed -10m)	850,768 cu m
AFTER	
$Total_{(2)}$ (above seabed -13m)	13,045,257 cu m
Ridge moved out	850,768 cu m
Trough filling (between -13 -10m)	911,936 cu m
Mound (above -10m)	345,617 cu m
$Total_{(2)}$ - $Total_{(1)}$ net gain	1,246,857 cu m
natural source	61,160 cu m
contribution of dumping	1,185,697 cu m
Distribution	
formed a mound cap above -10m	345,617 cu m
distributed over total area	840,079 cu m
Area of Dump Site	
0.75m increase in elevation over entire disposal area	
1.2m in elevation above coarse-grained mound	

TABLE 2. VELOCITY STATISTICS FOR WATER ABOVE THE DREDGED MATERIAL DISPOSAL AREA.

Meter Number	Location	Data Record (hrs)	Mean Directions	Durations of mean velocities for semi-diurnal cycle (hrs:min)	Durations of velocities > 22 cm/sec (hrs:min)	Durations of velocities > 30 cm/sec (hrs:min)	Vector mean velocities (cm/sec)	Total mean velocity (cm/sec)	Quality of directions consistency
1 May 7, 1973	Buoy A	31	On (282^o) Off (130^o)	6:39 6:30	0:10 0:00	0:00 0:00	12.9 11.9	12.4	Fair to good
2 May 7, 1973	Buoy B	31	On (302^o) Off (136^o)	5:20 6:45	1:18 0:32	0:00 0:00	16.6 14.4	15.4	Fair to V. good
3 May 23, 1973	Buoy C	30	On (289^o) Off (108^o)	6:54 5:48	1:30 0:08	0:00 0:00	16.1 16.7	16.4	Fair to good
4 May 23, 1973	Buoy C&D 2	26	On (313^o) Off (121^o)	7:48 4:37	1:12 0:00	0:00 0:00	15.1 9.7	12.1	Fair to good
5 July 27, 1973	Sand ridge -12m	67	On (303^o) Off (128^o)	5:54 6:00	4:18 0:00	0:48 0:00	16.7 10.8	13.8	V. good to excellent
6 July 27, 1973	Sand ridge -15m	68	On (301^o) Off (100^o)	5:06 6:42	0:00 0:06	0:00 0:00	12.0 14.7	13.4	V. good to excellent
7 Oct. 3, 1973	Sand ridge -5m	24	On (294^o) Off (123^o)	5:24 8:36	1:06 0:00	0:00 0:00	14.8 15.3	15.1	Excellent
8 Oct. 3, 1973	Sand ridge -16m	24	On (323^o) Off (122^o)	6:27 4:06	0:00 0:00	0:00 0:00	9.3 8.6	9.0	Poor
	TOTAL	301					AVERAGE	13.5	

ENVIRONMENTAL IMPACTS OF THE AQUATIC DISPOSAL OF DREDGED MATERIAL: FACT AND FANCY

by

Dr. Robert M. Engler*

Navigable waterways of the United States have, through the years, played a vital role in the nation's economic growth. The Corps of Engineers (CE), in fulfilling its mission to maintain, improve, and extend these waterways, is responsible for the dredging and disposal of large volumes of sediment each year. Dredging is a process by which sediments are removed from the bottom of streams, rivers, lakes, and coastal waters; transported via ship, barge, or pipeline; and discharged to land or water. Annual quantities of dredged material currently average about 300,000,000 cubic yards (186,000,000 dry tons) in maintenance dredging operations and about 80,000,000 cubic yards (48,000,000 dry tons) in new work dredging operations with the total annual cost now exceeding $150,000,000 (1).

In recent years, as sediments in many waterways and harbors have become contaminated, concern has developed that dredging and disposal of this material may adversely affect water quality or aquatic organisms. A number of localized studies have been made to investigate the environmental impact of specific disposal practices and to explore alternative disposal methods. However, these studies have not provided sufficient definitive information on the environmental impact of current disposal practices, nor have they fully investigated alternative disposal methods. As a result, the CE was authorized by Congress in the 1970 River and Harbor Act to initiate a comprehensive nationwide study to provide more definitive information on the environmental impact of dredging and dredged material disposal operations and to

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develop new or improved dredged material disposal practices. The U.S. Army Engineers Waterways Experiment Station (WES) was assigned the responsibility to develop and manage a comprehensive multidisciplinary five-year multimillion dollar research program known as the Dredged Material Research Program (DMRP). A more detailed planning, technical, and management structure can be found in references 2 and 3.

The DMRP is subdivided into four projects. The Environmental Impacts and Criteria Development Project (EICDP) will be discussed in this paper. The EICDP is further divided into six general task areas that are generally described by their respective titles. These tasks are: 1A - Aquatic Disposal Field Investigations; 1B - Movements of Dredged Material; 1C - Effects of Dredging and Disposal on Water Quality; 1D - Effects of Dredging and Disposal on Aquatic Organisms; 2D - Confined Disposal Area Effluent and Leachate Control; and 1E - Pollution Status of Dredged Material.

Task 1A includes major field investigations where field application of laboratory findings of the numerous biological, chemical, and physical investigations of open water disposal are underway. This task involves hopper dredge and barge disposal in freshwater, estuarine, and marine locations. Pipeline discharge investigations are being conducted as a part of Task 1B and 1E.

The development of mathematical models to predict dispersion and final fate of dredged material make up the general objectives of Task 1B.

Task 1C and 1D are involved with determining the effects of open-water disposal on water quality and aquatic organisms through laboratory investigations. Specifically, Task 1C is concerned with the mobilization and immobilization of chemical constituents during open-water disposal and longer term release after the material has settled to the bottom. Task 1D is concerned with the biological uptake and utilization of chemical constituents and the longer term physical and chemical effects on aquatic organisms through laboratory evaluations.

Task 2D involves the characterization of contaminant mobility within and from upland dredged material containment areas and the effects on the surrounding ecosystem.

Task 1E involves the previous listed investigations and combines their results with additional investigations to develop more meaningful and implementable regulatory criteria.

Fundamental to understanding the impact of sediment discharge and resuspension on water quality is an understanding of how chemical constituents, which may have various effects on aquatic organisms, are associated with dredged sediments.

Sediments may be separated into several components or phases which are classified by their composition and mode of transport to the estuarine environment. Among them are detrital and authigenic phases.

Detrital components are those which have been transported to a particular area usually by water. Detrital materials are derived from soils of the surrounding water-shed and can include (a) mineral grains and rock fragments (soils particles) as well as stable aggregates, (b) associated organic material, and (c) culturally contributed components derived from agricultural runoff and industrial and municipal waste discharges.

Authigenic components are those which are formed in place or have not undergone appreciable transport. These materials are generally the results of aquatic organisms and include (a) shell material ($CaCO_3$), (b) diatom frustules (SiO_2), (c) some organic compounds, and (d) products of anaerobic or aerobic transformations.

In considering the in-situ association with various sediment phases of trace elements in estuarine sediments, the water contained in inter-particle voids or interstices must be considered. This is termed interstitial water (IW). In relation to the overlying water, chemical constituents may frequently be enriched in the IW by several mechanisms. Some constituents (metals and some nutrients) are ionically bound to the sediment in several exchange locations; these include the exchange sites of the silicate phase and exchange sites associated with the organic matter or trace elements complexed with the organic phase. Heavy metals are also associated with hydrated manganese and iron oxides and hydroxides which are present in varying amounts in the sediment. Another location for heavy metals is in the sediment organic phase. The metals are incorporated into living terrestrial and aquatic organisms and are relatively stable but may be released into the sediment-water system during decomposition. The greatest concentration of chemical constituents however, is contained in the silicate mineral fraction (earth's crustal material) of a sediment.

From the previous discussion of elemental partitioning and for analytical purposes, the following categories of sediment components will be considered.

a. Interstitial water (IW). This water, an integral part of sediment, is in dynamic equilibrium with the silicate and organic exchange phases of the sediment as well as with the easily decomposable organic phase.

b. Mineral exchange phase. That portion of the element that can be removed from the cation exchange sites of the sediment using a standard ion-exchange extractant (NH_4OAc, dilute HCl, NaCl, $MgCl_2$, etc.).

c. Reducible phase. This phase is composed of hydrous oxides of iron and manganese as well as hydroxides of Fe and Mn, which are relatively reducing (anaerobic) conditions. Of particular importance are the toxic metals (Zn, Cu, Cd, Ni, Co, and Hg) that may be associated with these discrete Fe or Mn phases as occlusions or coprecipitates.

d. Organic phase. This phase or partition of elements is that considered to be solubilized after destruction of the organic matter. This phase contains very tightly bound elements as well as those loosely chelated by organic molecules. An initial extraction by an organic chelate may be needed to differentiate between the loosely bound and tightly bound elements.

e. Residual phase. This phase contains primary minerals as well as secondary, weathered minerals which are for the most part a very stable portion of the elemental constituents. Only an extremely harsh acid digestion or fusion will break down this phase. By far the largest concentration of metals is normally found in this fraction.

A particular element or molecule can be present (be partitioned) in a sediment in one or more of several locations. The possible locations include (a) the lattice of crystalline minerals, (b) the interlayer positions of phyllosilicate (clay) minerals, (c) adsorbed on mineral surfaces, (d) associated with hydrous iron and manganese oxides are hydroxides which can exist as surface coatings or discrete particles, (e) absorbed or adsorbed with organic matter which can exist as surface coatings or discrete particles, and (f) dissolved in the sediment interstitial water. These locations also represent a range in the degree by which an element may become dissolved in the receiving water. This range extends from stable components in the mineral lattices, which are essentially insoluble, to soluble compounds dissolved in the sediment interstitial water, which are readily mobile. Electrochemical (Eh, pH) changes after disturbing and resuspending anaerobic bottom sediments may result in possible solution or precipitation of many elemental species and should be thoroughly characterized.

A sediment characterization procedure to elucidate the phase distribution of contaminants in dredged material must be applicable to many types of marine and freshwater sediments, both aerobic and anaerobic. To be realistic, sediment disturbance must be minimal. Thus, drying, grinding, and contact with atmospheric oxygen is undesirable. Such a technique has been developed and subjected to preliminary evaluation (4). The sediment phases previously listed here are shown in their relative order of mobility and bioavailability. Interstitial water being most mobile and consequently most available. When contaminants enter a body of water it normally enters two or three fractions in varying concentrations but cannot be distinguished from natural levels by a bulk or total analysis. An example of the distribution of iron in a sediment from Mobile Bay, Alabama (5), has concentrations in the interstitial water (0.23% of total) exchangeable (2.13% of total) reducible (76.4% of total), organic (12.67% of total), and residual (8.55% of total). The total sediment iron concentration is 31,100 mg per Kg sediment. This residual phase, which contains the largest fraction of sediment copper, can only come in the solution during geologic weathering processes and have no acute or chronic biological impact. The organic phase may go through various transformations and a fraction of the organic portion could be rendered mobile. However, movement would be slow and solution copper would be rapidly diluted to ambient levels. These results only hint at the complexity of chemical constituents distribution within and among sediments; for a detailed discussion of sediment chemistry and water quality interrelations the reader is referred to references 5 and 6.

Results of the Task 1C, laboratory investigations of the impact of disposal on water quality, shows that ammonium, manganese, iron and ortho-phosphate were released from anaerobic sediments during disposal and initial mixing and after the sediment has settled to the bottom (7, 8). It was found, however, that the sediments scavenged or cleaned the water column of numerous toxic heavy metals and nutrients when contaminated fine-grained harbor sediments were dispersed in a water column. No release of chlorinated hydrocarbons was detected (7, 9) during the simulated open-water disposal of dredged material from a broad selection of marine, freshwater, and estuarine sediments. After the sediments had settled and formed a new sediment-water interface, several chemical constituent release and immobilization patterns were detected (7, 8, 9). Release from the sediments to the water column, with the exception of iron, manganese, and some nutrients, was extremely small. Several toxic heavy metals were released in concentrations less than one part per billion levels from either contaminated harbor sediments or noncontaminated sediments. It must be emphasized that these processes and transformations occur naturally in all sediments at similar levels (7, 8) and do not appear to be of a pollutional nature.

Further studies of chemical constituent release mechanisms (10) have evaluated conditions that enhance release of toxic metals when the sediment-water geochemical environment is drastically changed. As an example, the significant release of zinc to the water soluble phase was shown to occur at pH 5 under oxidizing (Eh) conditions. It must be emphasized that these acid-oxidizing, pH-Eh conditions do not normally occur in open-water disposal as anaerobic sediments normally remain near neutral pH and the oxidization processes that occur in the water column are not such as to result in an acidic condition (10). Subsequently, after the sediment settles it normally returns to an anaerobic and near neutral pH condition. On the other hand, if this sediment is placed in an upland containment area where oxidizing conditions can occur for a year or more and the sediments are high in total sulfide (common in many fine-grained estuarine sediments), the pH can become acidic and result in significant release of some contaminants (10) to the water soluble phase. Therefore, judicious selection of the disposal mode (open-water versus upland) and an understanding of the long-term implications of either disposal mode is very important. These previous observations and numerous other geochemical transformations of an extensive list of sediment constitutents are discussed in detail in references 7, 8, 9 and 10.

The previously reported research has suggested little release of most chemical constituents from dredged material, further emphasizing the need for determining the biological effect of chemicals associated with the sediment solid fraction. The physical effect, irrespective of chemical nature of this fraction, on various organisms must also be thoroughly evaluated. Investigations underway in Task 1D are determining the effects of turbidity (suspended dredged material) on aquatic organisms, the uptake of sediment-sorbed metals and pesticides, the ability of organisms to migrate vertically through deposits of dredged material, and the biological effects of sediment contained oil and grease.

Turbidity studies (11), conducted with marine, estuarine, and freshwater organisms have shown lethal concentrations of suspended dredged material to be significantly (an order of magnitude or more) higher than those concentrations observed in the field. In these laboratory studies the mortality of select organisms was demonstrated in concentrations of suspensions of dredged material exceeding 2-20 grams per liter (2,000 - 20,000 ppm) at 21-day exposure times. Field observations have shown turbidity or suspended particulate levels to be less than 1 gram per liter (1,000 ppm) for exposure times of only hours. Based on these and other observations, it was concluded that the physical effect of turbidity from dredged material discharge in open water would have minimal biological impact. Consequently, the primary impact of turbidity is of an aesthetic nature and must be controlled and treated as such. The only exception to this would be the sensitive coral reefs of Florida and Hawaii where low concentrations of suspended particulates can significantly impact large areas. Additional studies are currently underway to evaluate the uptake of contaminants from the suspended dredged material by aquatic organisms (benthic and water column) and will be completed later this year.

Other physical impact investigations underway in Task 1D are evaluating the ability of estuarine and freshwater benthic organisms to recover vertically after being covered or smothered by various loadings of dredged material (12). These laboratory evaluations are being conducted by the University of Delaware, Lewes, Delaware and have demonstrated that select organisms, (clams, crabs, and benthic worms), have been able to recover through as much as a meter covering or have been smothered by as little as a few centimeters covering of different types of dredged material. The organisms generally recovered through the deposits in a matter of hours, and minutes in some cases. These studies are investigating combinations of sand-dredged material deposited on mud and mud-dredged material on sand substrates. The most drastic biological impact was noted when unlike materials were placed on each other. Especially where a sand-dredged material was placed on a mud substrate and covered normally mud-dwelling organisms that were not suited for mobility through the sand or where sand-dwelling organisms were quickly smothered by a mud covering. Judicious selection of a disposal site where sand is placed on a sand bottom or mud on a mud bottom is imperative to minimize immediate or long-term physical impact at the site. Field studies in this task demonstrated that benthic organism recolonization (13) of dredged material mounds formed during disposal was relatively rapid and the processes were attributed in some part to vertical migration. However, a significant number of organisms also may be brought out with the dredged material and affect recolonization patterns.

Toxic heavy metal uptake studies (14) are a significant part of Task 1D and involve biological assessment of estuarine and freshwater shrimp, clams and benthic worms grown in contaminated sediments from the Houston Ship Channel, the Ashtabula River (Ohio), and other locations. The Houston Ship Channel sediments, highly contaminated with toxic heavy metals and chlorinated hydrocarbons, were generally toxic to a number of the organisms studied but were chosen as worst case material. This dredged material is not disposed in open water but confined in a land containment area. The organisms that lived through the experiments, however, did not appear to take up any toxic heavy metals. They did however, take up significant quantities of iron and manganese which have very limited if any toxicological properties. Zinc was the only other metal to show an accumulation trend. The uptake results could not be correlated to sediment bulk or total constituent concentrations. Freshwater studies with Ashtabula River sediments demonstrated that when freshwater worms from a clean environment were placed on the Ashtabula sediments, metals generally were taken up by these organisms. Uptake, however, reached concentrations exhibited in organisms that normally live in these sediments and did not exceed this level, and when the animals were transferred to clean sediments, they returned to their original or initial body burden. This study is nearing completion and will contribute significantly to the knowledge of metal uptake from contaminated sediments and its relation to aquatic disposal of dredged material. Pesticide uptake studies (15) have shown that maximum utilization by benthic organisms was from the interstitial water and minimum uptake from the solid sediment fraction. Perhaps, covering pesticide contaminated sediments with "clean" material at a disposal site will mitigate the organism utilization by isolating the contaminated material from the active benthic community that lives at or slightly below the sediment-water interface.

Task 1E investigations for the development of meaningful and implementable regulatory criteria for Public Laws 92-500 and 92-532 and other EICDP studies have shown conclusively that no relationship exists between "bulk" or "total sediment analysis" sediment characteristics and the effect of aquatic disposal on water quality or aquatic organisms (4, 5, 6, 7, 8, 9, 10, 16, 17, 18). These investigations have, however, shown that the "elutriate test" (19, 20) can be used to predict water quality perturbations and water column biological impacts (5, 6, 16, 17, 18). Further development and implementation of dredged material regulatory criteria have resulted in publication of "Interim Guidance" (20) for Section 404(b)1 of Public Law 92-500 pursuant to the 5 September Federal Register (21). This document, recently published and released by the WES, includes "cookbook" procedures and interpretive guidance for the Federal Register (21) and discusses procedures to be used for an ecological evaluation of the discharge of dredged and fill material in inland waters. The testing procedures include sediment analyses, water column evaluations, elutriate tests, water column bioassay, mixing zone estimations, and other physical and biological evaluations. Development of a benthic bioassay is currently a DMRP priority at WES, and under contract. It is envisioned that a benthic bioassay will be developed within the next twelve to twenty-four months. Field verification of the required regulatory procedures is underway at this time at numerous marine and freshwater locations (22) and will complement the completed laboratory research.

Large-scale field investigations of the short- and long-term physical, chemical, and biological impacts of open-water disposal are completed or nearing completion in Long Island Sound, Lake Erie near Ashtabula, Ohio, the Gulf of Mexico near Galveston, Texas, Puget Sound off Seattle, Washington, and in the Pacific Ocean off the mouth of the Columbia River (23). Chemical water-column effects duplicate the laboratory investigations previously reported in this paper, where only low levels of some nutrients and the metals iron and manganese were apparently released. Turbidity or suspended particulate was found to be in concentrations significantly, an order of magnitude or more, lower than concentrations shown to have an impact on a broad range of aquatic organisms (1) and persisted only a few hours. Significant impacts noted in these studies were the mounding of dredged material on the bottom of the dump sites. Biological recolonization studies of these mounds are incomplete at this time. However, there is initial evidence of rapid biological recolonization of some of the disposal areas. Sediment chemistry at the sites have shown elevated concentrations of chemical constituents in the sediment interstitial water at the disposal site as well as the control or reference areas. Movement or release of these chemical constituents out of the sediments of the disposal or reference sites was not apparent. Studies are incomplete where organisms at these sites are being analyzed for metals or chlorinated hydrocarbon uptake. However, initial evidence from the Eaton's Neck disposal site in Long Island Sound has shown no uptake of numerous toxic and nontoxic heavy metals by lobsters when compared with control or reference areas. These field studies will be completed by December 1976 and the final results, conclusions and recommendations published during the following several months.

Conclusions

1. The field evaluations are verifying results demonstrated in the laboratory investigations.

2. Water column impact during disposal appears minimal to nonexistant and effect is predominately aesthetic in nature.

3. Leaching of toxic heavy metals from the disposal mound into the water column appears no greater than from natural sediments of similar geologic character. Chlorinated hydrocarbon release was not detected. Nutrients were released to small concentrations greater than background.

4. The major bottom impact found at disposal sites was the physical mounding of the material. Benthic recolonization of the mounds appears relatively rapid.

5. "Bulk" or total sediment analysis does not relate to any mobile or bioavailable fraction of a sediment nor can it predict or evaluate water quality and ecological perturbations.

6. Water quality criteria and bioassay have been developed for Public Law 92-500 and 92-532 and are being field-verified at this time.

7. Toxic heavy metal uptake studies are incomplete but initial trends suggest minimal to no impact in marine and estuarine sediments.

8. Petroleum and chlorinated hydrocarbon uptake studies are incomplete at this time, however, initial trends suggest minimal uptake from solid phase of sediments.

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